2017 status muskoxen (*Ovibos moschatus*) Cape Atholl Thule region Greenland

Technical Report No. 104, 2022
Pinngortitaleriffik – Greenland Institute of Natural Resources

Title: 2017 status muskoxen (*Ovibos moschatus*) Cape Atholl, Thule region Greenland

Authors: Christine Cuyler[1], Kasim S. Virk[2], Thomas B. Clausen[2], Flemming H. Jensen[2], Erik W. Born[3], Kristin Laidre[1] and Øystein Wiig[4]

[1] Pinngortitaleriffik – Greenland Institute of Natural Resources, P.O. Box 570, 3900 Nuuk, Greenland
[2] SPE Box 140, 3970 Pituffik, Greenland
[3] Greenland's Representation, P.O. Box 1915, 1023 Copenhagen K, Denmark.
[4] Natural History Museum, University of Oslo, P.O. Box 1172 Blindern, 0318 Oslo, Norway

Series: Technical Report No. 104, 2022

Date of publication: 16 February 2022
Publisher: Pinngortitaleriffik – Greenland Institute of Natural Resources
Financial support: Pituffik Municipal Council (*Pituffik Borgerråd*)
Cover photo: Inge Gottfredsen: Muskox cows, calves, and juveniles, with Uummannap Kangerlua (Wolstenholme Fjord) in background, July 2017.

ISBN: 87-91214-81-5
ISSN: 1397-3657
EAN: 9788791214813

Cited as: Cuyler, C., Virk, K.S., Clausen, T.B. Jensen, F.H., Born, E.W., Laidre, K. and Wiig, Ø. 2022. 2017 status muskoxen (*Ovibos moschatus*) Cape Atholl, Thule region Greenland. Pinngortitaleriffik – Greenland Institute of Natural Resources. Technical Report No. 104. 60 pp.

Contact address: The report is only available in electronic format. You can download a PDF-file of the report at this homepage https://natur.gl/forskning/rapporter/

Pinngortitaleriffik – Greenland Institute of Natural Resources
P.O. Box 570
3900 Nuuk, Greenland

Phone: +299 36 12 00
E-mail: info@natur.gl
www.natur.gl

2017 status muskoxen (*Ovibos moschatus*) Cape Atholl Thule region Greenland

By

Christine Cuyler[1], Kasim S. Virk[2], Thomas B. Clausen[2], Flemming H. Jensen[2], Erik W. Born[3], Kristin Laidre[1] and Øystein Wiig[4]

[1] Pinngortitaleriffik – Institute of Natural Resources, P.O. Box 570, 3900 Nuuk, Greenland
[2] SPE Box 140, 3970 Pituffik, Greenland
[3] Greenland's Representation, P.O. Box 1915, 1023 Copenhagen K, Denmark.
[4] Natural History Museum, University of Oslo, P.O. Box 1172 Blindern, 0318 Oslo, Norway

Technical Report No. 104, 2022
Pinngortitaleriffik – Greenland Institute of Natural Resources

[Empty page]

Table of Contents

Figures

Tables

Appendices

Summary (English)

Muskoxen *(Ovibos moschatus*) once inhabited the Cape Atholl area (Kangaarsuk) between ca. 76° 14´ N and ca. 76° 35´ N in NW Greenland. In the 1800s, however, the muskox population in this area extirpated. In 1986, seven juvenile muskoxen were translocated from the Kangerlussuaq/Søndre Strømfjord region and re-introduced to the Cape Atholl area. The first systematic survey (September 2015) dedicated to muskoxen and covering almost half of the Cape Atholl area, resulted in a minimum count of 276 muskoxen. This report describes the second similar aerial minimum count (September 2017) and additionally a ground (road and sea) count of July-September 2017. The latter covered a smaller portion (14%) of the area than the aerial count (34%). Despite recent range expansion, the 2017 study indicated that most of the muskox population continued to remain concentrated in valleys and lowlands in the southern half of the Cape Atholl area. The ground count was 109 muskoxen, which included 8.3% calves (age < 1-year). The aerial minimum count was 212 muskoxen, which included roughly 10% calves. The aerial count was superior to the ground count in both area coverage and numbers of muskoxen observed.

At ca. 76°N, the Cape Atholl area is high Arctic and elevations above 200 m are sparsely vegetated. Despite this, the muskoxen have thrived since their re-introduction to the area. This appears related to the presence of huge seabird breeding colonies of little auks (*Alle alle*), whose annual guano deposition causes vegetation hot spots. In 2017, given minimum count of 212 muskoxen, density was ca. 1/km^2 for all areas with elevation <200 m and 4-5/km^2 for vegetation hot spots, while the 2017 calf percentage was low. Observations in 2021 by staff at the Pituffik – Thule Air Base suggest population decline has not occurred following 2017. To ascertain population trend, further aerial minimum counts are required and must include calf percentage value.

Eqikkaaneq (kalaallisut)

Avanersuarmi Kangaarsummi timmisartumik, Kangaarsuup affaata missaa, kisitsivigineqarmat ikinnerpaamik 276-inik umimmaqarnissaa missiliorneqarpoq. Kangaarsummi umimmaat ikinnerpaaffilerniarlugit september 2017-imi kisitsineq, kingullermik 2015-imi kisitsinermut sanilliunneqarsinnaavoq. Nalunaarusiami aamma ilanngullugu Kangaarsuup sineriaa atuarlugu umimmannik nunamiittuniik aammalu Pituffimmi biilimiit umimmaat takusat ikinnerpaaffilerniarlugit juli-september tungaanut 2017-imi kisitsivigineqarnerat ilanngullugit allaaserineqarput. Umiatsiamik taamatut Kangaarsummi kisitsinermi tamatuma nunataata 14 %-iata missaa kisitsiviuvoq, timmisartumilli kisitsinerup nunataata 34 %-iata missaanik kisitsiviulluni. Naak umimmaat siaruarfigisimasartik annertuseriarsimagaluaraat, taamaattoq Kangaarsuup kujataani qooqquniinniarnerusimapput atsissuniinniarnerusimallutillu. Umiatsiamit aqqusinermilu biilimiit kisitat 109-usimapput, taakkkunannga 8,3 %-ii piaraallutik suli ukiisimanngitsulluunniit. Timmisartumik kisitsinerup inerneraa Kangaarsummi ikinnerpaamik umimmaat 212 takuneqarsimasut, taakkua ilaat tassa 10 %-iisa missaat piaraallutik ukioq ataaserluunniit suli angusimanngikkaat. Ataatsimut naliliissagaanni timmisartumik kisitsineq umiatsiamiit aqqusinermiillu kisitsinerniit pitsaanerusutut nalilerneqarpoq, tassa kisitsiviup nunap annertussusia aammalu umimmaat takusat amerlassusiat eqqarsaatigalugit. Kanngaarsuup nalaata, avannarpasissuseq 76° N, silaannaa issittup silaannaa nillertuuvoq, immamiilllu qatsissuseq 200 meterit missaanniittoq nuna naggorluttuulluni. Pissutsilli taamaakkaluartut umimmaat taavungarsuaq nuussaallutik nunaligussat ajoriinnagassaanngitsumik aniguisarsimapput. Taama ajunngiusattumik atugaqarnerinut peqqutaavoq appaliarsuit ineqarfii, appaliarsuimmi anaat (guano) kuullutik nunamut eqqaamiorisaminnik naggoritsilluinnartarmata. Aallaavigigutsigu umimmaat ikinnerpaamik 212-iusut, taava km^2-mut eqimassusiat umimmaap ataatsip missaanniissaaq, naggorissoqarfimmilu km^2-mut sisamat tallimallu missaanniissaaq. Naak 2017-imi piaqqiarineqarsimasut ikiginakulukkaluartut, Pituffimmi sulisut 2021-mi oqaatigaat umimmaat eqqaminniittut ikiliartortutut isikkoqanngitsut. Kangaarsummilu umimmannut tunngatillugu pissutsit malinnaaffiginiarlugit innnersuussutigineqarpoq, aaqqissuulluakkamik timmisartumik kisitsinerit siunissami aggersumi ingerlateqqinneqartariaqaraluartut.

Resumé (dansk)

Moskusokser *(Ovibos moschatus*) forekom tidligere i Kap Atholl-området (Kangaarsuk) mellem ca. 76º 14´ N and ca. 76º 35´ N i Nordvestgrønland. Imidlertid forsvandt disse fra området engang i 1800-tallet. I 1986 blev moskusokser re-introduceret til Kap Atholl-området, da syv unge individer blev flyttet dertil fra Kangerlussuaq/Søndre Strømfjord. I september 2015 gennemførtes en første systematisk optælling, med det formål at optælle moskusokser i Kap Atholl-området. Denne flyoptælling, der dækkede halvdelen af Kap Atholl-området, resulterede i et minimumtal på 276 dyr. Denne rapport beskriver den anden - og med 2015-optællingen sammenlignelige - flyoptælling foretaget i september 2017 med det formål at få et estimat af minimumsantallet af moskusokser ved Kap Atholl. Rapporten beskriver også en optælling foretaget fra båd langs kysten og fra bil (vejnettet omkring Pituffik/Thule Air Base) i juli-september 2017. Sidstnævnte optælling dækkede ca. 14% af Kap Atholl-området, mens flyoptællingen dækkede ca. 34%. Til trods for at moskusokserne har udvidet deres generelle udbredelses-område, viste 2017-studiet at de stadig især var koncentreret i dale og de lavereliggende egne i den sydlige halvdel af Kap Atholl-området. Optællingen fra båd og vejnet gav et samlet tal på 109 moskusokser, hvoraf 8,3% var "under 1-år-gamle" kalve. Flyoptællingen resulterede i et minimumstal på 212 dyr, hvilket inkluderede 10% "under 1-år-gamle". kalve. Flyoptællingen var generelt bedre end båd- og vejnetoptællingen både hvad angår omfang af område, der blev dækket, og antal moskusokser set.

Omkring 76º N er klimaet i Kap Atholl-området højarktisk og områderne over 200 m over havets overflade (o.h.o.) har sparsom vegetation. Ikke desto mindre synes bestanden af re-introducerede moskusokserne at have klaret sig godt. Det skyldes især forekomsten i området af store fuglefjelde med søkonger (*Alle alle*), hvis afføring (guano) giver gødning til frodige vegetations "hot spots". Med udgangspunkt i minimumstallet på 212 moskus i 2017 var tætheden (densiteten) af dyr ca. 1 pr. km^2 i alle områder under 200 m o.h.o., mens den var 4-5 moskusokser pr. km^2 i disse "hot spots". Selv om procentdelen af nye kalve var forholdsvis lav i 2017, har observationer foretaget i 2021 af personale fra Pituffik ikke antydet en nedgang i antallet af moskusokser i området. For at følge udviklingen i bestanden i Kap Atholl-området anbefales det fremover at foretage systematiske flyoptællinger (minimumsantal samt andel af kalve).

Introduction

Cape Atholl is a sub-area (ca. 76° 30′ N; 69° W) within the Thule region of northwest Greenland (Fig. 1). The muskoxen inhabiting this sub-area were extirpated by harvest in the 1800's (Vibe 1986). About a century later, muskoxen were re-introduced and established a small population.

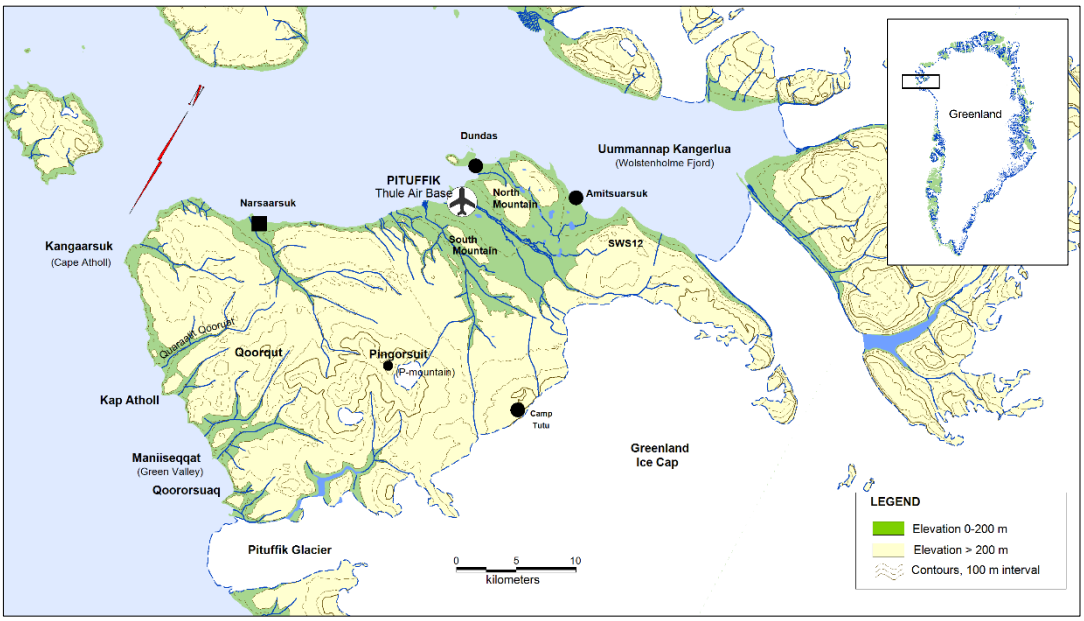

Figure 1. Map of the Cape Atholl area, which totals ca. 880 km², showing Pituffik – Thule Air Base, place names and the highest elevation, Pingorsuit (P-mountain) at 810 m.

Muskox translocation / re-introduction in 1986

In 1986, in the period 02–06 July, 27 ca. 14-month-old muskoxen were live captured at Kangerlussuaq (Søndre Strømfjord) (ca. 67° N, 51° W), using dogs, helicopters, and immobilising drug darts (Vibe 1986). Only seven of these yearling muskoxen, five females and two males, were destined for translocation to Cape Atholl. The remaining 20 yearlings were released further north in the Thule region, i.e., six in Mac Cormick Fjord and 14 in Inglefield Land. All the yearlings were ear tagged, packed into individual plywood crates, and flown by USA Air Force C141 freight airplane to the Pituffik – Thule Air Base. The 27 yearlings arrived at Thule on 11 July 1986 (details in Christiansen & Lacoppidan (1986)). Over the subsequent two weeks the muskox yearlings were transported to their final locations in the Thule region. The release locations, Cape Atholl, Mac Cormick Fjord, and Inglefield Land were decided by the local Thule member of the Greenland Home-rule parliament, Ûssarqaq Qujaukitsoq, in collaboration with the Thule Municipal Council (Cuyler et al. 2016). The seven Cape Atholl yearlings were airlifted, while inside their crates, by Air Greenland Bell 212 helicopter, to the

Maniiseqqat (Green Valley), on the south coast of Cape Atholl area. Some plywood crates can still be seen at the release site. The Maniiseqqat (Green Valley) release site was aptly named for its lush green vegetation, which is owing to the large annual deposition of seabird guano, specifically from the little auk (A*lle alle*) (Mosbech et al. 2018). Little auk breeding colonies are huge and numerous in the Thule region and create extensive thick plant cover on many slopes and valleys, specifically along the ca. 25 km long southern coast of the Cape Atholl area, e.g., from Kangaarsuk to the Pituffik Glacier (Fig. 1) (Boertmann & Mosbech 1998, Mosbech et al. 2018). Maniiseqqat translates to "the place with lots of [little auk] eggs". Near little auk colonies along the southern coast, polar foxtail grass (*Alopecurus alpinus*) is abundant and supports muskox densities 10 times higher than elsewhere in the Cape Atholl area (Mosbech et al. 2018). Further details regarding the muskoxen and the Cape Atholl area are described in Cuyler & Mølgaard (2002), and Cuyler et al. (2016). Green vegetation at little auk colonies is shown in Appendix 1.

Muskox population size and distribution

Incidental observations indicated that following re-introduction, muskoxen abundance increased slowly and that generally calf percentages were high (Table 1). Most of the population, and highest densities, have been in the southern portion of the Cape Atholl area, and usually near little auk colonies (Cuyler et al. 2016, Mosbech et al. 2018). In 2012 and 2013 (4-11 September and 7-17 September, respectively) systematic observations of muskoxen were made during aerial searches for polar bears (*Ursus maritimus*) (Born et al. 2012, 2013, Born, Laidre & Wiig unpublished), brief methods provided in Appendix 2. The polar bear search path did not cover the entire Cape Atholl area but followed the seacoast with one exception. On return from the Thule Air Base to the south of Melville Bay on 10 September, a diagonal path across the Cape Atholl area was included (Fig. 2). The polar bear search encompassed the shorelines of Cape Atholl and the entire Melville Bay. Despite this, no muskoxen were observed south of the Cape Atholl area i.e., east, or south of the Pituffik Glacier. 39 muskoxen were observed in 2012, and in 2013 observations indicated 155 to 196 muskoxen (Fig. 3). Since the maximum, 196, may include double counting of animals present in the Maniiseqqat (Green Valley), we assume 155 muskoxen as the minimum count for 2013. These recent sightings suggested that muskoxen remained numerous in the valleys along the southern coast of the Cape Atholl area, specifically in the Maniiseqqat and Qoororsuaq valleys, and that none were present east or south of the Cape Atholl area.

Table 1. Muskox observations in Cape Atholl since 1986 re-introduction indicating group size and calf percentages. Excepting 1986 re-introduction and 2015 minimum count of entire Cape Atholl area, all observations were opportunistic and cannot indicate abundance. Blank cells indicate absence of data.

Year	Location	Muskox number[1]	Calf number[2]	Calf %	Composition
1986 [a]	Maniiseqqat	7	0	0	Mixed
1990 [b]	Maniiseqqat	7	0	0	Mixed
1991 [b]	Maniiseqqat	7	2	28.6	Mixed
1993 [b]	Inner Narsaarsuk (Pingorsuit)	6			Mixed
1994 [a]	Maniiseqqat	19	7	35.0	Mixed
1994 [a]	Maniiseqqat	1	0	0	Solitary bull
1995 [a]	Maniiseqqat	24	7	26.9	Mixed
1995 [a]	Maniiseqqat	1	0	0	Solitary bull
1995 [a]	Maniiseqqat	1	0	0	Solitary bull
1996 [a]	Maniiseqqat	33	8	24.2	Mixed
1997 [c]	Maniiseqqat + Narsaarsuk [d]	32	7	21.9	Mixed
1997 [c]	Maniiseqqat + Narsaarsuk [d]	12	5	41.7	Mixed
1997 [c]	Maniiseqqat + Narsaarsuk [d]	1	0	0	Solitary bull
1997 [c]	Maniiseqqat + Narsaarsuk [d]	1	0	0	Solitary bull
1997 [c]	Maniiseqqat + Narsaarsuk [d]	1	0	0	Solitary bull
1998 [e]	Maniiseqqat	10	1	7.1	Mixed
1998 [e]	Maniiseqqat	1	0	0	Solitary bull
1998 [e]	Maniiseqqat	1	0	0	Solitary bull
1998 [e]	Maniiseqqat	1	0	0	Solitary bull
1998 [e]	Maniiseqqat	1	0	0	Solitary bull
2001 [e]	Maniiseqqat	18	5	23.8	Mixed
2001 [e]	Maniiseqqat	1	0	0	Solitary bull
2001 [e]	Maniiseqqat	1	0	0	Solitary bull
2001 [e]	Maniiseqqat	1	0	0	Solitary bull
2002 [e]	Unspecified	30-35			Mixed
2002 [e]	Unspecified	51	14	27.5	Mixed
2003 [e]	Maniiseqqat	40	5	12.5	Mixed
2003 [e]	Maniiseqqat	12	2	16.2	Mixed
2003 [e]	Maniiseqqat	1	0	0	Solitary bull
2003 [e]	Maniiseqqat	1	0	0	Solitary bull
2003 [e]	Maniiseqqat	1	0	0	Solitary bull
2003 [e]	Maniiseqqat	1	0	0	Solitary bull
2003 [e]	Maniiseqqat	1	0	0	Solitary bull
2012 [f]	South coast Cape Atholl area	39			Mixed
2013 [f]	South coast Cape Atholl area	155			Mixed
2015 [g]	Entire Cape Atholl area	276	48	17.4	Mixed

[1] These are the group size (1986 – 2003) or total number (2012, 2013, 2015) of muskoxen observed.
[1] These are the number of calves already included in the previous column for group size or total number muskoxen observed.
[a] Burnham 1997
[b] Peter Nielsen pers. comm.
[c] Local Knowledge provided to the Government of Greenland, Ministry for Environment & Nature
[d] Previously one cohesive group, now appears to have separated into at least two groups and several lone bulls. Hoof hyperplasia on muskoxen observed in both valleys.
[e] Cuyler & Mølgaard (2002).
[f] Aerial count in conjunction with polar bear survey, September (Born et al. 2012, 2013 and Born, Laidre & Wiig, unpublished).
[g] Aerial minimum count for muskoxen of Cape Atholl, September (Cuyler et al. 2016).

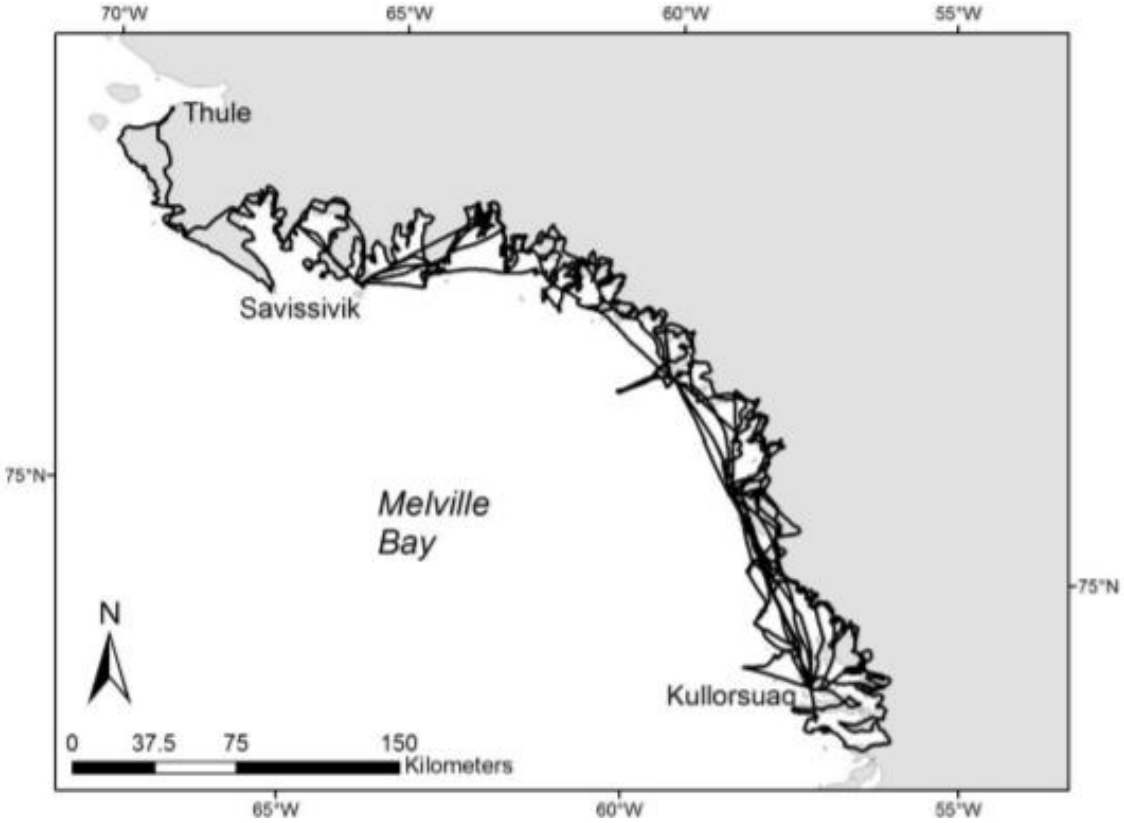

Figure. 2. Flight paths during survey for polar bears between Kullorsuaq and the Pituffik – Thule Air Base, 4-11 September 2012 (Born et al. 2012). Only the upper northwest portion involved the Cape Atholl area. The flight path during 7-17 September 2013 was similar.

After the 1986 re-introduction muskox distribution was concentrated in the Maniiseqqat (Green Valley) (Burham 1996). Nevertheless, muskoxen slowly expanded their range use to include the entire southern coast (Pituffik glacier to Kangaarsuk (Fig. 1), and finally moved northward toward the Pituffik – Thule Air Base (Cuyler et al. 2016). In 2015 an aerial minimum count, specifically for muskoxen, was flown by fixed-wing Cessna 172 and covered 46% of the Cape Atholl area. A minimum of 276 muskoxen were observed and revealed a calf percentage of 17.4% (Cuyler et al. 2016), which is relatively low compared to values prior to 2003. The 2015 count indicated muskoxen were still concentrated in the valleys and lowlands of the southern portion of the Cape Atholl area, but also observed 41 near the Pituffik – Thule Air Base in the north. In fact, by spring 2015 sightings of muskoxen in the northern portion of the Cape Atholl area near the Pituffik – Thule Air Base were becoming common. By spring 2017 there was an increase in the number of groups sighted and group sizes. Also, that spring, a local hunter, Olennguaq Kristensen, observed a lone muskox near the village of Savissivik. At least one muskox had moved east and south of the Pituffik glacier/Cape Atholl area.

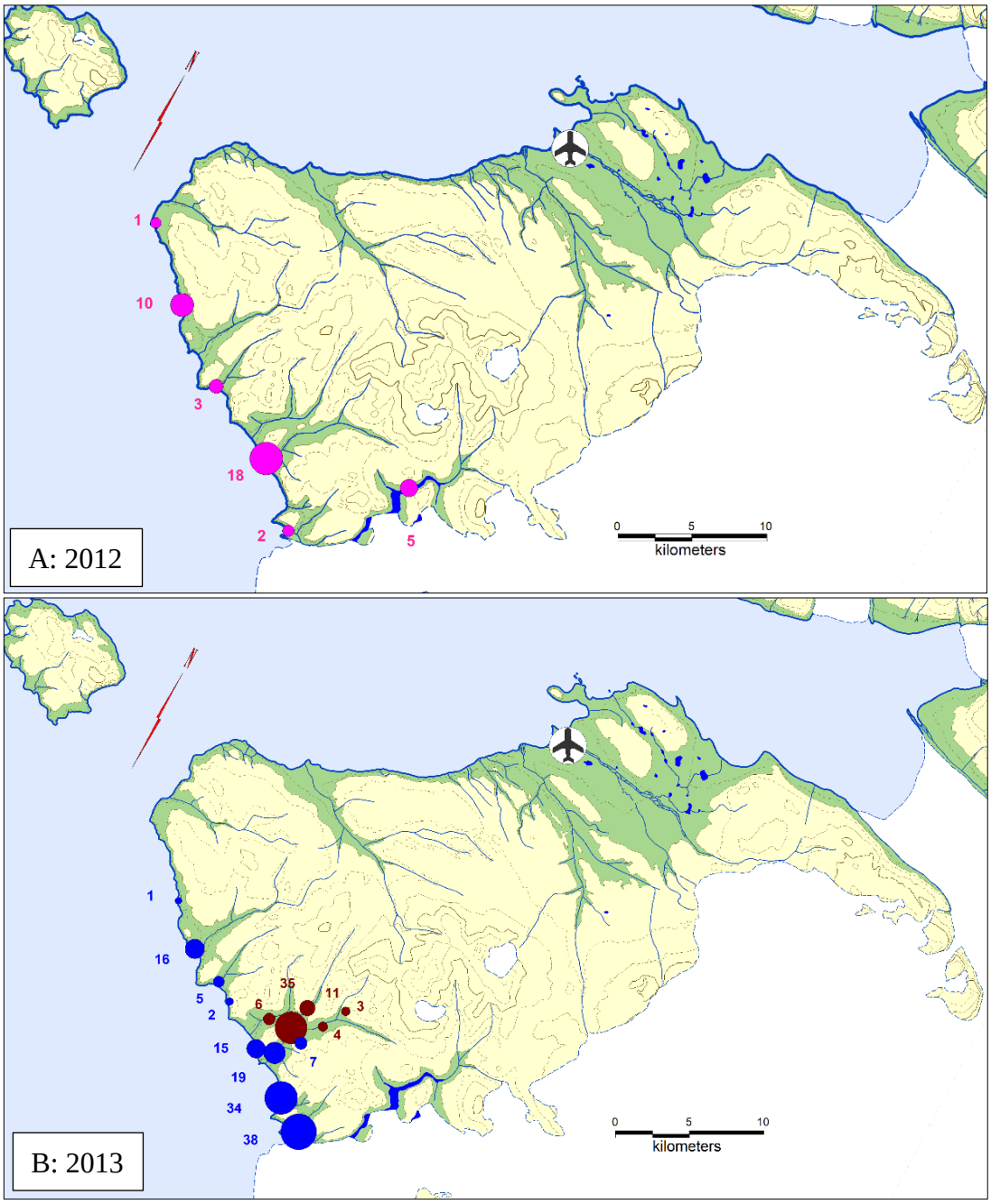

Figure. 3. Incidental observations of muskoxen made during flights searching for polar bears (Born et al. 2012, 2013, Born, Laidre & Wiig unpublished), (A) 7 September 2012, (B) 9 and 10 September 2013 (blue and brown respectively).

Harvest

Hunting of the re-introduced muskoxen on Cape Atholl was prohibited for the first 15 years (Table 2), although in the 1990's two culls occurred to examine severe hoof hyperplasia (overgrown hooves). The first cull, in 1996, involved just one bull muskox. The second, in 1998, culled 14 muskoxen of mixed sex and age (Cuyler & Mølgaard 2002). Hunting began in 2001 with a quota of five muskoxen. From autumn 2007 to spring 2016, the hunting season was nine months long (August to April inclusive) with a quota of 15

muskoxen annually. Reported harvests seldom utilized the entire quota. Given the 2015 count observed 276 muskoxen, which included 17.5% calves combined with Pituffik – Thule Air Base staff reporting vegetation damaged by muskoxen in lowlands (elevations < 200 m), Cuyler et al. (2016) recommended preventing population growth. The annual harvest quota rose from 5% (n=15) of the observed 2015 minimum count to 14.5% (n=40). The length of the hunting season remained at nine months. An additional five trophy bulls were permitted, but as of the time of this study none were reported taken. Meanwhile, incidental muskox sightings in spring 2017 suggested continued range expansion and similar calf production as in 2015.

Table 2. Harvest quotas and seasons for muskoxen of Cape Atholl. Reported shot is incomplete following 2000, and five years completely lack hunter reporting. Blank cells indicate absence of data.

Year	Season	Quota Commercial / Sport	Reported shot
1986	Hunting prohibited	0	0
1990	Hunting prohibited	0	0
1991	Hunting prohibited	0	0
1993	Hunting prohibited	0	0
1994	Hunting prohibited	0	0
1995	Hunting prohibited	0	0
1996[a]	Autumn cull 1 bull: examined hooves	0	1
1997	Hunting prohibited	0	0
1998[b]	April cull of 14: overgrown hooves study	0	14
1999	Hunting prohibited	0	0
2000	Hunting prohibited	0	0
2001[c]		5	3
2002[c]		5	
2003[c]		5	
2004/2005[c]	1 Aug – 30 Sept 2004, 1-31 March 2005	7	
2005/2006	1 Aug – 15 Nov 2005, 1 Jan – 30 Apr 2006		2
2006/2007			
2007/2008[c]	1 Aug 2007 – 30 Apr 2008	15	11
2008/2009[c]	1 Aug 2008 – 30 Apr 2009	15	2
2009/2010[c]	1 Aug 2009 – 30 Apr 2010	15	
2010/2011[c]	1 Aug 2010 – 30 Apr 2011	15	15
2011/2012[c]	1 Aug 2011 – 30 Apr 2012	15	3
2012/2013	1 Aug 2012 – 30 Apr 2013	15	10
2013/2014[c]	1 Aug 2013 – 30 Apr 2014	15	7
2014/2015	1 Aug 2014 – 30 Apr 2015	15	8
2015/2016[d]	1 Aug 2015 – 30 Apr 2016	15	3
2016/2017[d]	1 Aug 2016 – 30 Apr 2017	40	27*
2017/2018[d]	1 Aug 2017 – 30 Apr 2018	40	
		Trophy Quota	
2015/2016[c]	1 July – 31 Oct 2015; 15 Feb – 30 Apr 2016	5	0
2016/2017[c]	1 July – 31 Oct 2016; 15 Feb – 30 Apr 2017	5	0
2017/2018[c]	1 July – 31 Oct 2017; 15 Feb – 30 Apr 2018	5	

[a] Burnham 1997
[b] Cuyler & Mølgaard 2002
[c] Ministry for Hunting and Fishing (APN), unpublished data.
[d] Individual hunter reports/licenses filled in by hunters.
* Two muskoxen were reported shot close to the remains of turf houses at Dundas, which is immediately across the small bay at the Thule Air Base. This location is outside of the designated Cape Atholl hunting area.

Present Study

We examined the 2017 muskox distribution and abundance in the Cape Atholl area by completing both ground and aerial minimum counts. We began with the ground minimum count, which was conducted by boat, truck, and all-terrain vehicle (ATV) from 24 July to 06 August. When possible, a detailed demographics (sex and age composition) of each group was obtained. On 14 September 2017, we completed an aerial fixed-wing minimum count of the Cape Atholl area. This report presents the results from these counts of muskoxen on Cape Atholl, which include the observed autumn distribution, total counts, calf percentage and demographics.

Methods

Study area

At ca. 76°N, the Cape Atholl area's location is approximately halfway between the Arctic Circle and the North Pole. Total area is ca. 880 km^2, of which only 202 km^2 are under 200 m elevation. The Cape Atholl area has a somewhat rectangular shape, which is bounded to the North, West, and South by the sea and to the East by the Greenland Ice Cap, of which the southeast glacial tongue is known as the Pituffik Glacier. To the north is Uummannap Kangerlua (Wolstenholme Fjord), which is thick with ice bergs originating from three glacial tongues of the Greenland Ice Cap. The area's topography is characterised by open expanses that stretch west from the front of the Greenland Ice Cap, interrupted only by the Pingorsuit (P-mountain) massive and two long ridges named the North and South mountains. The Pingorsuit massive consists of five rounded peaks. The highest is 810 m. All five have gentle slopes. Two peaks are visible from the road network and share a permanent ice patch. With the notable exception of the Pituffik – Thule Air Base/Dundas area, the area's coast lines are generally exposed steep slopes with narrow shoreline/beach below. Safe harbours are few to non-existent.

The Cape Atholl area is high arctic with cool short summers and NDVI (Normalized Difference Vegetation Index) is generally low (Mosbech et al. 2018). Even in July, green is not a common colour in the typically light brown landscapes of the Cape Atholl area. The exceptions can include riverbanks, some valleys near the Thule Air Base, and most markedly, the steep slopes lining the south coast, which are also punctuated by several vivid green

vegetated ravine-like valleys. The presence of multiple little auk colonies is responsible for the extent of lush green vegetation along the south coast's slopes and valleys (Mosbech et al. 2018). Elsewhere, vegetation is sparse and low in stature. All willow (*Salix* spp.) and birch (*Betula* spp.) hug the ground, with their flowering parts sticking straight up to only about 4-5 cm above the soil. Grasses seldom reach more than a height of 10 cm.

In addition to muskoxen, other mammals present in the Cape Atholl area include only the arctic hare (*Lepus arcticus*), arctic fox (*Vulpes lagopus*), and the occasional polar bear (*Ursus maritimus*) or caribou/reindeer (*Rangifer tarandus* spp.). Notable by their continued absence are lemmings (*Dicrostonyx groenlandicus*) and polar wolves (*Canis lupus arctos*). Albeit regarding the latter, in 2021 tracks of a single canid were observed near the Pituffik – Thule Air Base. However, no animal was observed, and it was difficult to ascertain whether the tracks were from a wolf, or a loose Greenland sled dog. Although uncommon, in the past loose sled dogs have occurred near the Pituffik – Thule Air Base. To date and for the past 30 years, polar wolves have never been observed or shot near the Pituffik – Thule Air Base or elsewhere in the Cape Atholl area (Kasim Virk pers. comm.).

For clarity, it is worth noting that the Cape Atholl area has two locations sharing that name (Fig. 1). The first, Kangaarsuk (Cape Atholl), has both Greenlandic and English names, and is the region's southwest cape. The second is a promontory known to Pituffik locals by the Danish name, Kap Atholl, is midway on the southern coast of the region. For further description of the study area see Cuyler et al. (2016), while Appendix three contains several photos illustrating the Cape Atholl area.

Survey design

Ground count: road and sea

From 24 July to 06 August 2017, a muskox minimum count and demographics was completed by the Greenland Institute of Natural Resources (GINR) in collaboration with the Pituffik Municipal Council. Owing to either rain or storm force winds, which forced closure of the road network and prohibited sailing, this count took place on just 4 days (24, 26 & 29 July and 06 August). Participants included Christine Cuyler (senior scientist, GN), Kasim S. Virk (Chair, Municipal Council for Pituffik – Thule Air Base), and Inge Gottfredsen (photographer). We sailed the coastline on the evening of 24 July. On 26 and 29 July we drove the principal roads near the Pituffik – Thule Air Base. On 06

August, ATVs were used to reach the far northeast portion of the Cape Atholl area. Observed muskoxen were assigned a grid-cell position (Fig. 4).

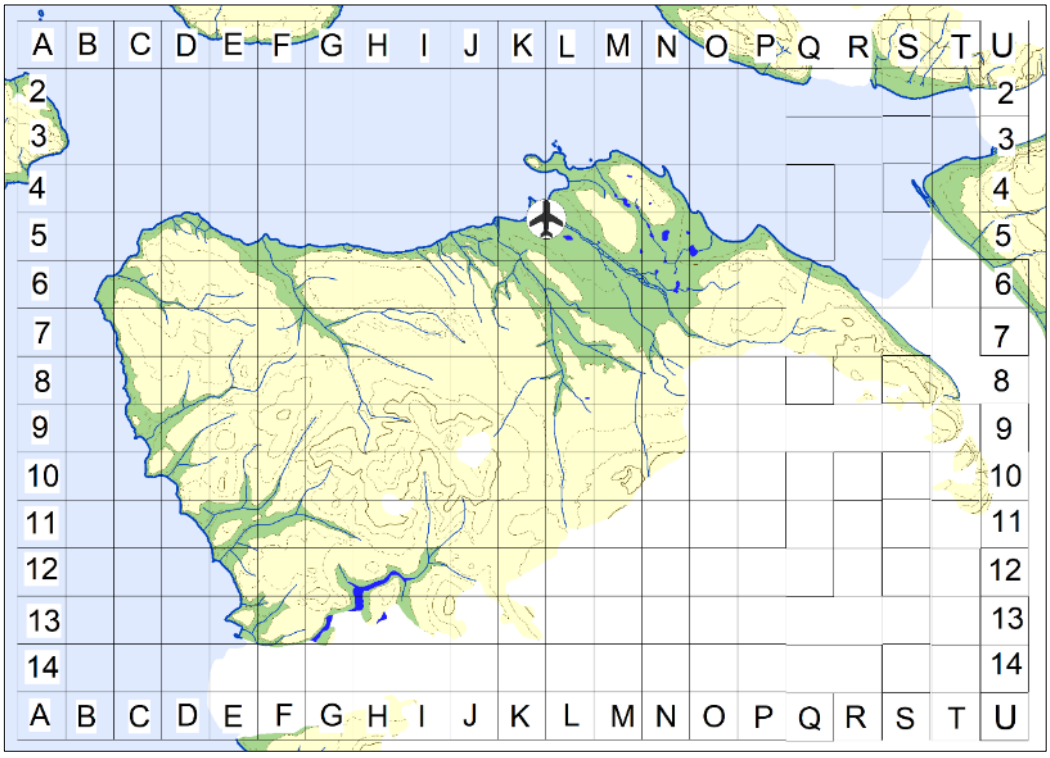

Figure. 4. Map of the grid cells used during the 2017 muskox counts of Cape Atholl area. Each square measures 3x3 km

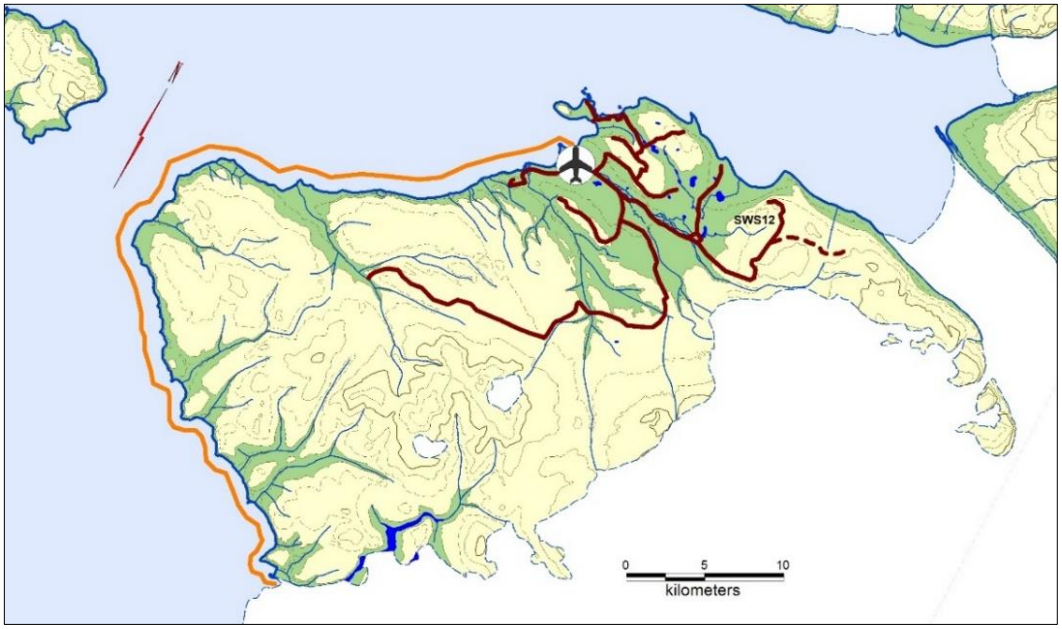

Figure. 5. Ground: road and sea routes used for July 2017 minimum count of muskoxen in Cape Atholl: sailing (solid orange line), roads driven (solid brown lines) and ATV route (dashed brown line).

Using Leica telescope or binoculars (32-x and 10-x magnification respectively), each muskox group was then examined for total number, and the sex and age

of the individuals (Appendix 4, 5). Calves were identified by their small body size. Sex and age of older animals were determined by horn size/shape and body size (Henrichsen & Grue 1980, Olesen & Thing 1989, Alaska Dept. of Fish & Game 2010). To avoid double counting, once an area, valley or coast had been counted it was considered 'finished' and never counted again. For example, near the Pituffik – Thule Air Base, several groups and individuals were assumed seen repeatedly in the same areas throughout the study period. We sailed approximately 55 km of coastline and drove about 93 km of roadway/track (Fig. 5). Strip width for the coastline was about 500 m, and twice that for roadways driven. Therefore, the road and sea area surveyed totalled about 120 km^2, providing approximately 14% coverage of the Cape Atholl area. We noted arctic fox, arctic hare, and ringed seal (*Pusa hispida*) sightings.

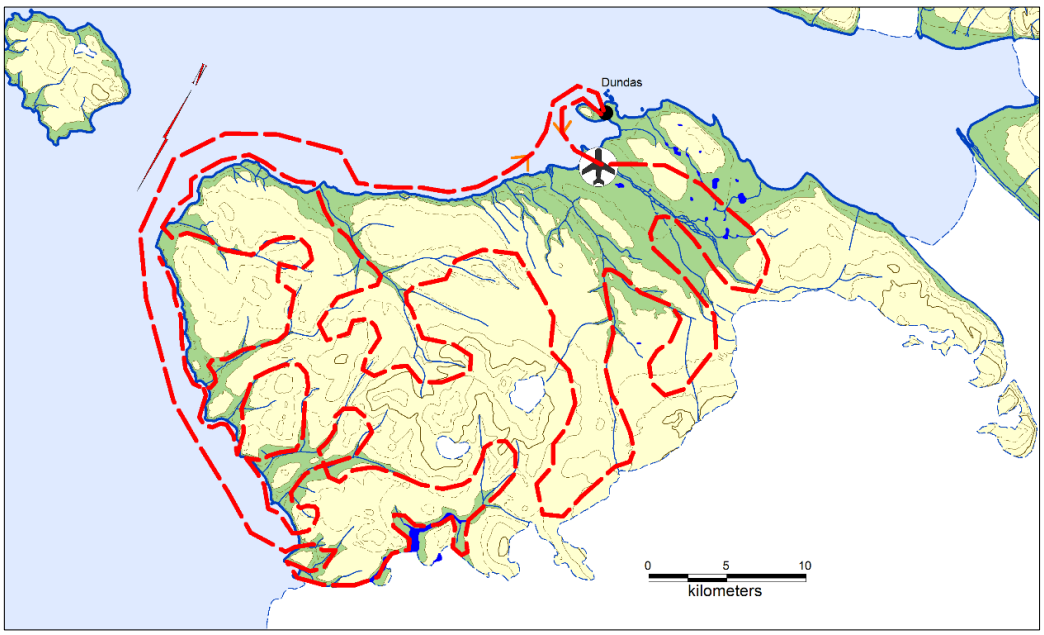

Figure 6. Aerial route flown for 14 September 2017 minimum count. Total path length (including ferry return to Thule Air Base) was 360 km, which included the ca. 300 km for actual muskox count. Orange arrows near the Dundas start and end point indicate flight direction.

Aerial fixed-wing count

On 14 September, from 17:45 until 21:30, a muskox minimum count was completed by the Pituffik Municipal Council. A Cessna, single engine, 4-seat, high fixed-wing aircraft was used to fly over the Cape Atholl area. Observers, Kasim S. Virk (Chair, Municipal Council for Pituffik – Thule Air Base) and Thomas B. Clausen (Pituffik – Thule Air Base) sat on either side of the airplane. Steen Svensson (Pituffik Flying Club) was the pilot. Muskox groups observed were assigned a grid cell position and the total number of

individuals were written onto the grid map (Fig. 4). When possible, the number of observed calves (age < 1-year) was included. Calves were identified by their small body size. Given the stationary nature and slow locomotion of muskoxen, double counting (counting the same group or individual twice) was avoided and assumed impossible by surveying the entire Cape Atholl area in under four hours.

Cruising speed was 175 km per hour. Strip width varied but was about 500 m to either side of the line flown. Survey altitude was generally like the 2015 survey, i.e., about 400 m ±100 (1000 – 1500 feet). Flying time was 3 hours and 45 minutes. This is about 1½ hours more than flown in 2015. The greater time used in 2017 resulted from the combination of three things. First, the heavy winds and falling snow along the southern shoreline's steep slopes created dangerous conditions, which required a greater altitude and made flying close to the steep coastal slopes impossible. The result was multiple time-consuming attempts to fly the assigned route. Secondly, was the aerial photography of the Qoororsuaq vegetation, which required additional circling with the aircraft. Finally, following completion of the Cape Atholl area, a side-trip was flown to south of the Pituffik Glacier for the purpose of photographing the vegetation there. The Cape Atholl portion of the route was about 360 km in length, of which ca. 300 km were for the actual muskox count, and the remaining for ferry return to the Pituffik – Thule Air Base (Fig. 6). Resulting area coverage was about 34% of the Cape Atholl area's 880 km^2.

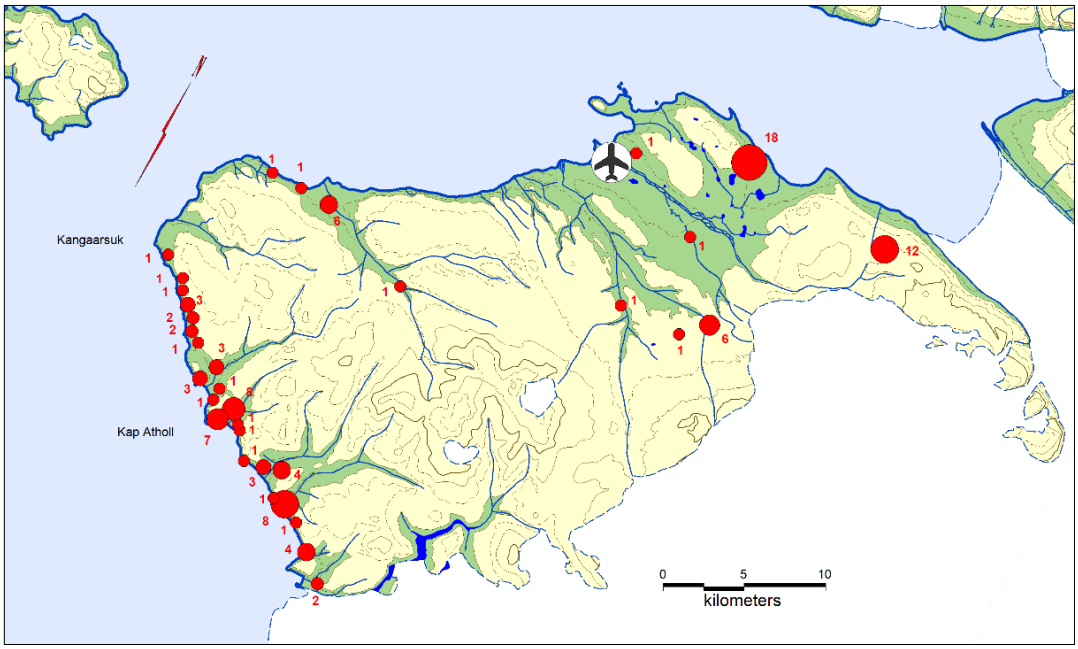

Figure 7. Location and size of muskox groups observed during the road and sea minimum count of the Cape Atholl area, July 2017

Results

Ground: Road and sea minimum count July-August 2017

We observed 35 groups of muskoxen, for a total of 109 animals (Fig. 7), which included 9 calves (born spring 2017). Calves made up only 8.3% of all animals observed on the road and sea count. Average group size was 3.1 ±3.7 StDev (Standard Deviation). Maximum group size was 18 muskoxen.

The number of muskoxen in the north near the Pituffik – Thule Air Base amounted to 37% (n= 40) of the total observed during the ground count. These included just three groups of mixed sex and age, and four solitary bulls (Fig. 7). Meanwhile, 63% of all the muskoxen observed were in the southern half of the Cape Atholl area. For the first time, we observed muskoxen foraging on the upper half of the extremely steep slopes of the south coast, specifically from Kangaarsuk south to Cape Atholl. High above on the slopes, several muskoxen were only detected once they stood up. Initially these were hidden from our view because they were lying down in pits, which were necessary to prevent inadvertently rolling down the steep incline.

Table 3. Muskox demographics from ground (road and sea) minimum count of Cape Atholl, July 2017.

Muskox demographics in Cape Atholl: Ground Count			
Classification	**Age**	**Observed**	**Percentage**
Unknown	1-2 years	10	9.2 %
Unknown	≥3-years	15	13.8 %
Calf	< 1 year	9	8.3 %
Cow	1-year	2	1.8 %
Cow	2-years	5	4.6 %
Cow	3-years	3	2.8 %
Cow	≥ 4-years	19	17.4 %
Bull	1-year	2	1.8 %
Bull	2-years	8	7.3 %
Bull	3-years	5	4.6 %
Bull	4-years	5	4.6 %
Bull	≥ 5-years (Trophy)	26	23.8%
	TOTAL	**109**	**100 %**
			Ratio
	Bull (≥ 5-yrs) / cow (age ≥ 3-yrs)	26 bulls: 22 cows	1.2: 1
	Recruitment (calves/100 cows (age ≥ 3-yrs)): Maximum	9 calves: 22 cows	40.9: 100
	Recruitment (calves/100 cows (age ≥ 3-yrs)): Minimum	9 calves: 29 cows	31.0: 100

77% (n = 84) of the muskoxen were successfully sexed and aged (Table 3). With age based on their body size, sex could not be determined for 15 animals (age ≥ 3 years) and 10 sub adults (age 1-2 years). Using only cows with known sex and age, the maximum mid-summer calf recruitment was roughly 41 calves per 100 cows. However, the bull to cow ratio suggests the possibility of seven cows among the 15 animals of unknown sex but age ≥ 3-years. This suggests a minimum calf recruitment of roughly 31 calves per 100 cows. Calf percentage was only 8.3% of the total number of observed muskoxen, while reproductively mature cows (i.e., age ≥ 3-years) were just 20.2%.

Miscellaneous observations during ground count

Observations of other species included 27 arctic hare, 8 arctic fox and 2 ringed seals (*Pusa hispida*). Mosquitoes were present, but the typically strong winds kept harassment level low.

During the count period, weather conditions were generally unfavourable (storm force winds and rain) for travel, except for sunshine and light winds on 24 and 25 July. Regardless, the Cape Atholl area's open vistas and low vegetation height aided sighting muskoxen over great distances.

Generally, the muskoxen appeared somewhat disturbed by our presence, whether this was sailing by in a boat or driving past using a motorized vehicle. If on a slope, they moved up and away from their initial positions. If in open terrain near a road they moved away in the opposite direction. Distances moved ranged from only a few meters to ca. 0.5 km.

On the extremely steep but vegetated slopes of the southern shoreline, one sub adult male (age 2-years) evidenced an injured right hind leg. No weight could be put on the limb, which made movement laborious on the steep incline. This sub-adult was closely accompanied by a cow.

On the 26th of August 2017 the first incidence of natural mortality was observed. A muskox bull was found dead beside the road just east of North Mountain (Pituffik – Thule Air Base). The absence of any black colour at the horn tips, which were also blunt and rounded with wear, suggest that this animal was an old bull well past his prime. About three weeks later, a polar bear was scavenging the carcass (Appendix 6).

This 2017 study observed hoof hyperplasia (i.e., overgrown) on one muskox (Appendix 7). The condition afflicted just one leg and hoof length was only somewhat more than normal. Pituffik – Thule Air Base staff has reported few if any observations of hoof hyperplasia in recent years.

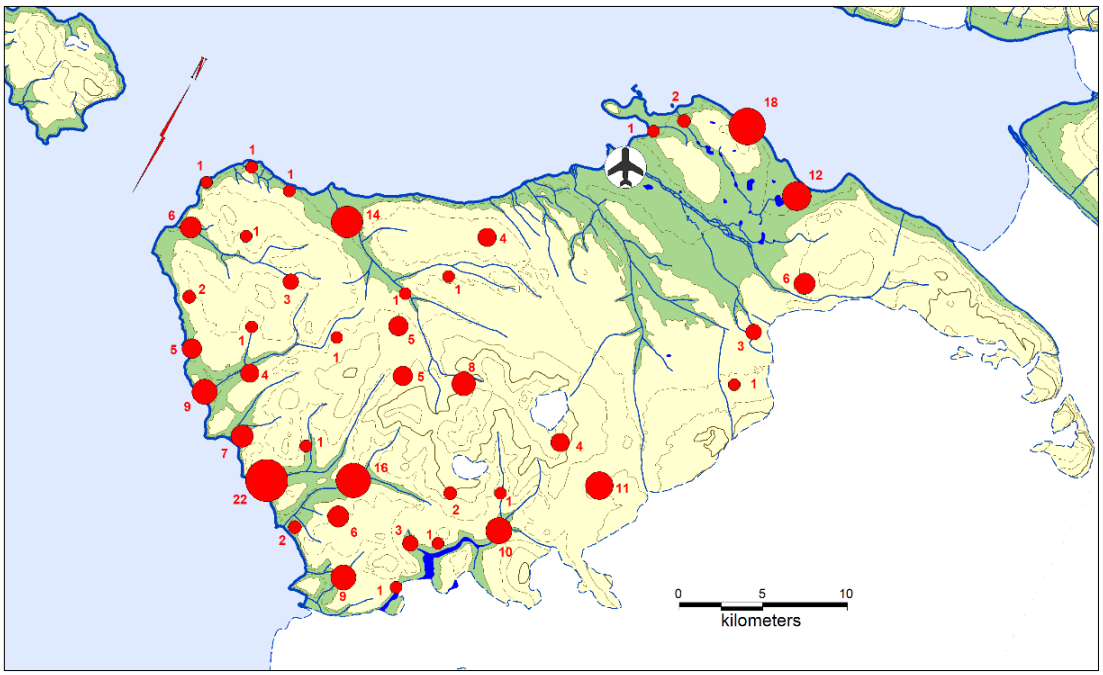

Figure 8. Location and size of muskox groups observed during the aerial survey of Cape Atholl area, 14 September 2017. A total of 212 muskoxen were observed.

Aerial fixed-wing minimum count September 2017

From the fixed-wing aircraft we observed 41 groups of muskoxen, for a total of 212 animals (Fig. 8, Table 4). This included 21 calves (born spring 2017, age < 1-year). Calves made up ca. 10% of all animals, however, this rough value may be low because the presence or absence of calves was not always possible to ascertain. Average group size was 5.2 ± 5.2 StDev. Maximum group size was 22 and occurred at the mouth of the Maniiseqqat (Green Valley).

The majority, 80% (n=169), of all the muskoxen observed were in the southern half of the Cape Atholl area, albeit many were approaching the ½-way point between the north and the south. The remaining 20% (n= 43) of all muskoxen observed were in the northern portion of the area. These included the same three mixed sex and age groups observed earlier in the ground (road and sea) count (i.e., the groups containing 6, 12 and 18 muskoxen), while three of the ground count's lone bulls appeared to have become a group of three. For the northern Cape Atholl area, the aerial count observed three more muskoxen than the ground count, specifically a group of two and a lone adult.

Table 4. Aerial minimum count results for muskoxen of Cape Atholl, 14 September 2017.

Parameter	Muskoxen Survey of Cape Atholl
Continuous survey line distance	300 km
Survey line width	1 km (2x 500m)
Cape Atholl area	880 km^2
Approximate surveyed area	300 km^2
Survey coverage	34%
Aircraft altitude	300-500 m
Air Speed	175 km/hour
Number of muskox groups observed	41
Total muskoxen observed	212
Observed calves among total[1]	21
Rough calf percentage[1]	9.9 %
Average group size	5.17 ± 5.2 StDev
Median group size	3
Maximum group size	22
Minimum group size	1

[1] Presence or absence of calves could not be ascertained with certainty for 12 of the 41 groups (Appendix 5, Table 6). Thus, the calf percentage is approximate and may be lower than the true value.

Weather conditions deteriorated as the aerial survey progressed, specifically while attempting to survey the ca. 25 km southern shoreline between Kangaarsuk and the Pituffik Glacier. Specifically, strong gusting winds prohibited flying low over the shore cliffs between Kangaarsuk and Cape Atholl. Additionally, snow began to fall, which obscured visibility, specifically when combined with the higher altitudes flown. The result was reduced observer ability to detect muskoxen that may have been present on the slopes of the southern shoreline.

Discussion

Muskox distribution and abundance

Although 43 muskoxen were observed in the northern half of the area, the 2017 results illustrate that most of the muskox population continue to remain concentrated in the valleys and lowlands of the southern half of the Cape Atholl area. Nevertheless, the 2017 count documented northward expansion and hunter observation revealed at least one lone bull had managed to cross the barrier that is the Pituffik glacier, since it was on the southeast side near the village of Savissivik. This 2017 distribution suggests that even at this study's count of 212 muskoxen, the muskox population of Cape Atholl is expanding its range. Range expansion can be a mechanism to counteract overpopulation on initial range area.

In 2017 we completed both an aerial and a ground (road and sea) count. The ground count covered ca. 14% of the Cape Atholl area (total ca. 880 km^2), while the aerial coverage was more than double at 34%. This difference was reflected in the number of muskoxen observed. The ground count observed 109 muskoxen, while the aerial count had almost double at 212. The aerial results suggest a muskox density of 0.2/km^2 for the entire Cape Atholl area.

On any count some animals are always overlooked. Muskox detectability at the time an area is counted can be affected by several factors, including weather. During the aerial count of 2017, sometimes blowing snow obscured visibility while strong winds prevented low altitude flying over the best muskox habitat (southern shore of Cape Atholl area. It is likely that some of muskoxen were not detected. Thus, the 2017 aerial minimum count result, 212 muskoxen, likely missed animals present along the route flown. With its lower total number of muskoxen observed relative to the aerial effort, the ground (road and sea) count obviously missed muskoxen that were otherwise present in the Cape Atholl area. During the sea count unusual circumstances somewhat explain the fewer ground count observations. When we sailed the coast on 24 July, the number of muskoxen observed (n=68) amongst the little auk colonies of the southern shoreline was low. We sailed that coast in the evening, unaware that earlier that same day two research ornithologists from Aarhus University, Denmark, had sailed the same shoreline and gone ashore into all the main valleys to complete field work. To protect themselves from possible muskox attacks they had deliberately scared the muskoxen out of those valleys (Mosbech pers. comm.). Understandably, few muskoxen remained when we counted those valleys that evening. The above, however, does not fully explain the 103 fewer muskoxen observed during ground efforts. Clearly, owing to greater coverage and increased animal detections, aerial counts are superior to ground counts.

Until 2012 there had been no specific effort to count muskoxen in the Cape Atholl area. Any observations were anecdotal, often limited to just the Maniiseqqat and/or Narsaarsuk valleys, and not unexpectedly muskox numbers were modest (Table 1). Since re-introduction of muskoxen to the area in 1986, there have been four aerial minimum counts. The first two, 2012 and 2013, were systematic observations of muskoxen made during aerial survey dedicated to detecting land-locked polar bears. These, however, did not cover the entire Cape Atholl area. The third and fourth, 2015 and 2017 (this study), were aerial counts specific for muskoxen, covered the Cape

Atholl area, and document the minimum number of muskoxen in Cape Atholl. The 2015 aerial count observed 276 muskoxen, which was the largest observed number to date and documented population growth since release of seven muskoxen almost 30 years earlier. The 2017 aerial count observed 212, which is 64 fewer muskoxen than in 2015. Considering only the 25 km stretch of prime habitat on the southern coast, the 2017 result was 79 observed muskoxen, which contrasts sharply with the 118 muskoxen observed along the same shoreline in the 2015 aerial count. The adverse weather conditions, which created difficult conditions for detection of muskoxen during the 2017 aerial count, may have resulted in an artificially low number of muskoxen observed. Alternatively, perhaps the increased harvest quotas since 2015 (recommended by Cuyler et al. (2016)) had succeeded in halting population growth. Certainly, the 2017 count suggests possible decline in population size but with just two counts for comparison that conclusion is debatable.

Calf production

The calf percentage from the aerial count is acknowledged rough and likely lower than the actual value, since calves can easily remain undetected during such a survey. Regardless, even if a few percentage points are added the value would still be considered low relative to previous values. Further, the accurate ground count calf percentage, 8.3%, indicates the aerial value is reasonable.

In 2017, we observed that 2-year-olds were ca. 16.5% of all muskoxen observed (Table 3), which is only marginally lower than the percentage observed for this cohort two years previous, i.e., 17.4% calves in 2015 (Cuyler et al. 2016) and indicates low mortality. In contrast, the percentages for yearlings (born 2016) and 2017 calves were exceptionally low, i.e., yearlings ca. 8.2% and calves 8-10% (Tables 3, 4). The poor values suggest either high natural calf mortality or low calf production.

Regarding mortality, large predators are not assumed a major factor causing calf mortality because these are normally absent from the Cape Atholl area. In 2017, a polar bear was observed scavenging an adult muskox carcass (Appendix 6). Although polar bear predation of muskoxen is rare, predation events by adult bears on typically lone adult bulls have been recorded in North America (Tener 1965) and Greenland (Thing 1984). In 2015, a dead calf was found on the beach at Maniiseqqat (Green Valley) and predation by polar

bear was suggested since bears were regular visitors to the Maniiseqqat (Torbjørn Jørgensen pers. comm.).

It is well known that occasional Greenland sled dogs occur running loose near the Pituffik – Thule Air Base (Kasim Virk pers. comm.). Regarding wolves, for the past 30 years, none have been observed or shot in the Cape Atholl area (Kasim Virk pers. comm.). Of course, if wolves were present in the Cape Atholl area that might help explain the low 2017 calf percentage. Regardless, their presence has not yet been documented. Still, it is worth mentioning that polar wolves inhabit Ellesmere Island (Canada) and Washington Land and Hall Land (northwest Greenland) (Dalerum et al. 2018). Ellesmere Island is ca. 275 km west from Cape Atholl, and while both the latter are also in northwest Greenland, they are about 400 and 600 km north of the Cape Atholl area. Closer and in 2008, the Greenland Government received word from Siorapaluk hunters that wolves were observed north of the village in Inglefield Land (Charlotte Bülow pers. comm.), which is about 200 km north of the Cape Atholl area. Further, in the recent past, at least two wolves have been shot by local hunters in Prudhoe Land, just over 100 km north of the Cape Atholl area. The first in May 2014 by a hunter from the hamlet, Qeqertat, and the second in September 2015 by a hunter from the village, Qaanaaq (Qillaq Danielsen pers. comm.). By 2015, Qaanaaq residents felt wolves were becoming increasingly common in their area and assumed the wolves were arriving from either Canada's Ellesmere Island or moving south from Washington Land (Paviaraq Jakobsen pers. comm.). With wolves present to the north, there is clearly the potential for them to move south into the Cape Atholl area in the future. Nevertheless, a substantial obstacle, to this potential range expansion by polar wolves, is the Government of Greenland's Executive Order No. 33 of 11 September 2020 (Selvstyret 2020), which permits commercial hunters unlimited hunting of polar wolves, year-round, in the Qaanaaq wildlife management area (Inglefield- and Prudhoe Land). To date, the presence of wolves has yet to be confirmed for the Cape Atholl area.

For the present, mortality causes also include weather events e.g., survival of muskox calves in Alaska and Norway is negatively correlated with spring snow depth (Reynolds 1998, Asbjørn et al. 2005). Observations by locals at Pituffik – Thule Air Base indicate that the winter 2016/2017 included greater than normal snow depth and that spring snowmelt arrived late in 2017. During the ground count period, 24 July – 06 August, much snow remained in patches even at sea level, although low elevation terrain was almost

completely snow-free. Mortality due to weather may have affected the 2016 and 2017 cohorts.

Additionally, low calf production may be responsible for the low percentages of calves and yearlings in 2017. Calf production and survival is highly correlated with cow body condition (Cuyler et al. 2022) and the hard winter and late spring of 2017 may have negatively affected cow body condition. Poor cow body condition negatively impacts pregnancy rate, calf birth weight, and milk production (Adamczewski & Flood 1997, White et al. 1997, Adamczewski et al. 1998). Overall calf production also depends on the number of sexually mature cows, and from the ground count mature cows only accounted for 20.2% of the observations. Regardless, given the number of cows observed, autumn calf recruitment was a poor 31-41 calves per 100 cows.

There were just 8-10% calves in 2017. Regardless of what factors are responsible that value may be enough to support stability since the eastern Greenland muskox population was assumed stable in the period 1982-1994 and 10.5% calves were observed in 1994 (Born et al. 1995). 8-10% calves are, however, likely too low to support growth in the muskox population of Cape Atholl. Given large predators are generally absent from the Cape Atholl area, natural mortality (harvest not included) among muskox adults may be similar to North American caribou populations without predators, i.e., from 4 to 8% (Bergerud 1967, 1971, Skoog 1968, Kelsall 1968, Heard & Ouellet 1994). This suggests the 2017 calf percentage was roughly equivalent to adult mortality making population growth improbable. Additionally, and again regarding caribou, when calf percentages fall below ca. 14% then population decline is inevitable (Bergerud et al. 2008). Further, and for North American muskox populations, calf percentages of 17-24% may be necessary to facilitate population growth (Jingfors & Klein 1982, Gunn et al. 1984). If the low 2017 calf percentage continues unchanged then population decline is possible for muskoxen in Cape Atholl.

Habitat and forage

Muskoxen generally forage in low lying valleys and coastal areas (Nellemann & Reynolds 1997, Nellemann 2011, Anderson & Fergusen 2016). Optimal muskox habitat is generally below 200 m elevation, while below 100 m elevation supports the highest densities of muskoxen (Thomas et al. 1981). The Cape Atholl area is just 880 km^2 and its high latitude at ca. 76°N, means

forage decreases rapidly with rising elevation (Körner 2007). Unfortunately, regarding forage for muskoxen of Cape Atholl, 77% of the area is above 200 m elevation, with just 202 km^2 below 200 m. Compensating for lack of lowlands is the presence of the little auk. The Thule district of Northwest Greenland is this small seabird's most important breeding area for the North Atlantic, with ca. 33 million pairs that nest in huge colonies (Boertmann & Mosbech 1998; Egevang et al. 2003). While most colonies are in scree slopes along the seacoast, in some areas breeding colonies can extend up to 11 km inland (Mosbech et al. 2018). Large colonies occur along the steep slopes and valleys of the Cape Atholl area's 25 km long southern coast (Boertmann & Mosbech 1998). The NDVI, which quantifies vegetation greenness, within 600 m of a little auk colony is well above average owing to guano deposition, which causes vegetation hotspots (Mosbech et al. 2018). Not unexpectedly since re-introduction in 1986 most of the muskox population forages the slopes and valleys close to little auk breeding colonies (Burnham 1996). The area that is both below 200 m elevation and associated with little auk breeding colonies is, however, only about 44 km^2, or 5% of the Cape Atholl area.

Year-round grazing and trampling since 1986 combined with the 2015-2017 population size of a minimum 212–276 muskoxen suggest declining habitat quality is possible, e.g., overall quantity of food available. Three observations support the likelihood of reduced forage. First, the 2017 observations of muskoxen for the first time grazing near the tops of extremely steep slopes on the southern coast. Secondly, the 2017 numerous muskox groups located far north of the little auk breeding colonies of the southern coast, despite abundance not being greater than in 2015. Finally, the low percentage of calves and yearlings in 2017. Already by 2015, Pituffik – Thule Air Base staff reported lowland vegetation (willows) damaged by muskoxen, while visiting raptor scientists noted muskoxen had torn-up the tundra alongside streams and rivers (Cuyler et al. 2016). The latter may be what Mosbech et al. (2018) documented, i.e., areas of exposed soil at the base of steep hillsides under little auk colonies caused by muskoxen rubbing their bodies against the incline. Given the Cape Atholl area's otherwise low NDVI (Mosbech et al. 2018, Appendix 3), the 212 muskoxen observed in 2017 may be too many for the limited area (44 km^2) of good forage associated with little auk breeding colonies. Albeit colonies are extensive on the southern coast, and guano is deposited anew annually, the vegetation hot spots around little auk colonies are not limitless.

Movement is a fourth indicator of reduced food resources relative to the number of herbivores on a range, and often leads to greater movement in search of forage. The expanded muskox distribution observed in 2017 supports decreased food quantity. Recent increased muskox movement is also supported by the current lack of what was once almost universal hoof hyperplasia in the 1990's. In the 1990's the muskoxen were described as unmoving and feeding in the lush vegetation under little auk breeding colonies (Burnham 1996). At that time, hoof hyperplasia was endemic throughout the muskox population of Cape Atholl, with lack of movement and too rich a diet among the probable causes (Cuyler & Mølgaard 2002). In 2017, however, only one muskox, a bull, was observed with the condition, which involved a single hoof and overgrowth was slight (Appendix 7, Fig. 40) relative to the excessive hoof lengths observed in the 1990s (Cuyler & Mølgaard 2002). This indicates the cause of the single 2017 case was pathogenic rather than genetic, dietary, or owing to lack of movement. Today's normal hoof lengths suggest greater muskox movement and a diet less rich than previously. The latter is supported by the hyperplastic bull's advanced incisor tooth wear, despite being relatively young (age 5-6 years). This contrasts sharply with the 1998 total absence of incisor tooth wear regardless of age (maximum 13-years) in 14 sampled muskoxen (Cuyler & Mølgaard 2002). Thus, albeit just one animal, the bull's worn-down incisors indicate a diet of poor browse, which may be affecting others in the population as well.

Muskox density

The 2015 and 2017 counts indicate presence of at least 212 to 276 muskoxen, which suggests a density range of 0.2-0.3 muskox/km^2 for the entire 880 km^2 Cape Atholl area. However, only 5% (44 km^2) is lowlands associated with little auk colonies, which provide forage hot spots for muskoxen. Not surprisingly, below little auk colonies, group sizes are double that of elsewhere on Cape Atholl and adult muskox density may be as high as 3.9/km^2 (Mosbech et al 2018). Indeed, given the 212 muskoxen observed in 2017, density at the hot spots might be ca. 4.8/km^2. This exceeds best estimate for high Arctic muskox stocking density, i.e., 1-2 muskoxen/km^2 for year-round foraging on good lowland habitat where winters are not too severe (Thomas et al. 1981); however, this was not referring to excellent habitat under bird colonies. Still, muskoxen prefer to forage anywhere that elevations are < 200 m, although for Cape Atholl green vegetation is sparce beyond the little auk breeding colonies (Appendix 1, 3). For Cape Atholl, elevations <200

m are an area of 202 km^2, and the 2017 density now approaches 1.1 muskoxen/km^2, which is within that proposed by Thomas (et al. 1981) making the 2017 population size, 212 muskoxen, perhaps appropriate for the habitat available, if winters are not too severe. Whether the number of muskoxen observed in the 2015-2017 period are within the current herbivore carrying-capacity of the Cape Atholl pasture/range remains to be seen.

Large herbivores can exert density-dependent influences on their own population dynamics through grazing, trampling, disease transmission, and competition with each other (Joly & Klein 2016). Grazing and trampling at Cape Atholl's vegetation hot spots, i.e., preferred habitat under little auk breeding colonies, has been documented (Mosbech et al. 2018). At the Qoororsuaq little auk colony, muskoxen have transformed the vegetation from being dominated by mosses to being dominated by polar foxtail grass, the valley almost taking on the appearance of a pasture (Mosbech et al. 2018). The foxtail grass has expanded into areas that were characterized by mosses before the muskoxen were re-introduced, indicating that at least at the little auk colonies muskoxen have changed the plant community to their own grazing advantage (Mosbech et al. 2018). Still, given the high northern latitude and that the area involving these vegetation hot spots is small, a muskox population of 200 or more individuals may exceed the overall food quantity, specifically when severe winters limit food availability.

When the quantity of food available is reduced then poor nutritional body condition among muskoxen can result and have negative consequences for calf production. Muskox cow pregnancy rates are sensitive to nutritional influences, which if poor, lead to reproduction declines (Adamczewski & Flood 1997, White et al. 1997, Adamczewski et al. 1998). Muskox cows require 22% body fat to have a 50% probability of pregnancy (Crête et al. 1993, Adamczewski et al. 1998, Pachkowski et al. 2013), so naturally, the probability of successful breeding during the rut increases with the body mass of cows (Rowell et al. 1997, White et al. 1997). The low 2017 calf percentage, 8-10%, supports the speculation that the pasture quality in the overall Cape Atholl area has declined as muskox numbers rose, and that current pasture can no longer support cow body condition sufficient to produce the previously observed 24-35% calves (Table 1). Given the 2017 minimum count of 212 muskoxen, limited habitat available, high latitude and sparse vegetation in the Cape Atholl area, a population size above the number of animals observed in 2017 may be unsustainable.

Population trend

The muskox population of Cape Atholl appears to have thrived since seven individuals were re-introduced to the area in 1986. Nevertheless, the low 2017 calf percentage indicates that at least recent conditions for calf production/ survival have not been good. Although not investigated by this study, conditions might include reduced range quality and snow depths. If the observed low calf percentage accurately reflected the 2017 situation and if it persisted, then population decline is possible. There have been no further muskox counts since 2017.

In 2021, Pituffik – Thule Air Base staff provided an update on muskox presence for the area surrounding the Air Base. The new information suggested the low calf percentage of 2017 had not persisted. In 2017 only 43 muskoxen were counted near the Pituffik – Thule Air Base. In contrast by 2021, over 100 muskoxen were observed, group sizes were sometimes over 20 animals and typically included many calves, and for the first-time lone old bulls became a nuisance and safety hazard at the Pituffik – Thule Air Base runway (Kasim Virk pers. comm.).

Reasons for the 2021 greater numbers of muskoxen around the Thule Air Base would include of course population growth but could also be attributed to ordinary movement into the area from elsewhere on Cape Atholl owing to damaged vegetation in the primary habitat around little auk breeding colonies. For the latter, population growth would not necessarily be a prerequisite. Meanwhile, alone, the 2015 and 2017 counts provide just two points of reference. This is insufficient data to establish muskox population trend. Further counts are required.

Acknowledgements

The Pituffik Municipal Council was pivotal in initiating and carrying out the 2017 counts. We gratefully thank the pilot Steen Svensson and the Pituffik Flying Club for once again providing their Cessna 172 to disposition for the aerial survey minimum count. We sincerely thank Svend Guldager Pedersen, Site Manager for Greenland Contractors, for the financial support covering flights to and from Thule, accommodation, and meals. We thank anonymous reviewer for critique of the manuscript.

Literature cited

Alaska Dept. of Fish & Game. 2010. Muskox, a guide to identification hunting and viewing. Alaska Department of Fish & Game, P.O. Box 1148, Nome, Alaska 99762, USA. www.wildlife.alaska.gov. 36 pp.

Anderson M. & Fergusen M. 2016. Movements and habitat use of muskoxen (*Ovibos moschatus*) on Barthurst, Cornwallis and Devon Islands, 2003.2006. Status Report 2016-08, Nunavut Department of Environment, Wildlife Research Section, Igloolik, NU. 112 pp.

Asbjørn et al. 2005. Predicting the growth of a small introduced muskox population using population prediction intervals. *Journal of Animal Ecology*. 74: 612-618.

Boertmann D. & Mosbech A. 1998. Distribution of little auk (*Alle alle*) breeding colonies in Thule District, northwest Greenland. *Polar Biol*. 19: 206-2010.

Born E.W., Laidre K. & Wiig Ø. 2012. Genetic mark-recapture assessment of the Baffin Bay and Kane Basin polar bear subpopulations: Interim report on field work 2012. – Unpublished report to the Department of Fishery, Hunting and Agriculture (Government of Greenland, Nuuk) and the Danish Environmental Protection Agency (Ministry of the Environment), Copenhagen, from the Greenland Institute of Natural Resources, 7 November 2012, Nuuk, 21 p. (Available from the Greenland Institute of Natural Resources, www.natur.gl).

Born E.W., Laidre K. & Wiig Ø. 2013. Genetic mark-recapture assessment of the Baffin Bay (BB) and Kane Basin (KB) polar bear subpopulations: Interim report on field work 2013. – Unpublished report to the Department of Fishery, Hunting and Agriculture (Government of Greenland, Nuuk) and the Danish Environmental Protection Agency (Ministry of the Environment), Copenhagen, from the Greenland Institute of Natural Resources, 10 December 2013, Nuuk, 19 p. (Available from the Greenland Institute of Natural Resources, www.natur.gl).

Born E.W., Wiig Ø. & Neve P.B. 1995. Observations of muskoxen (*Ovibos moschatus*) in Central East Greenland. *Z. Säugetierkunde* 60: 373-379.

Burnham W. 1996. Progress Report 1996: Thule Greenland Project. The Peregrine Fund, 566 W. Flying Hawk Lane, Boise, Idaho 83709, USA. 10 pp.

Burnham W. 1997. Progress Report 1997: High Arctic Institute Pituffik, Greenland. The Peregrine Fund, 566 W. Flying Hawk Lane, Boise, Idaho 83709, USA.

Christiansen T & Lacoppidan C. 1986. Transport af moskusokser på Grønland i 1986. Intern Report samt 3 Bilag. 7 pp.

Cuyler, C., Marques, T.A., Correia, I.J.F., Jensen, A., Hegelund, P. & Wagnholt, J. 2022. 2018 status muskoxen, Maniitsoq & Sisimiut, West Greenland. Pinngortitaleriffik – Greenland Institute of Natural Resources. Technical Report No. 119. 113 pp.

Cuyler L.C. & Mølgaard H.S. 2002. Overgrown hooves from muskoxen (*Ovibos moschatus*) of Kangaarsuk (Cape Atholl) Northwest Greenland. Greenland Institute of Natural Resources. Technical report No. 41. 30 pp.

Cuyler C., Virk K.J., Clausen T.B. & Jensen, F.H. 2016. 2015 status Cape Atholl muskoxen (*Ovibos moschatus*) Thule region Greenland. Greenland Institute of Natural Resources. Technical Report no. 96. 37 pp.

Dalerum F., Freire S., Angerbjörn A., Lecomte N., Lindgren Å, Meijer T., Pečnerová P. & Dalén. L. 2018. Exploring the diet of Arctic wolves (*Canis lupus arctos*) at their northern range limit. *Canadian Journal of Zoology*. 96: 277-281.

Henrichsen P. & Grue H. 1980. Age criteria in the muskox (*Ovibos moschatus*) from Greenland. *Danish Review of Game Biology*. 11(4): 1-18.

Joly K. & Klein D. R. 2016. Complexity of caribou population dynamics in changing climate. U.S. National Park Service. www.nps.gov

Körner C. 2007. The use of 'altitude' in ecological research. *Trends Ecol. Evol.* 22: 569–574.

Mosbech A., Johansen K.l., Davidson T.A., Appelt M., Grønnow B., Cuyler C., Lyngs P. & Flora J. 2018. On the crucial importance of a small bird: The ecosystem services of the little auk (*Alle alle*) population in Northwest Greenland in a long-term perspective. *Ambio*. 47: S226-S243.

Nellemann C. & Reynolds P.E. 1997. Predicting late winter distribution of muskoxen using an index of terrain ruggedness. *Arctic and Alpine Research* 29(3): 334-338.

Nellemann C. 2011. Habitat use by muskoxen (*Ovibos moschatus*) in winter in an alpine environment. *Can. J. Zool.* 76(1): 110-116.

Olesen C.R. & Thing H. 1989. Guide to field classification by sex and age of the muskox. *Can. J. Zool.* 67: 1116-1119.

Reynolds P. 1998. Dynamics and range expansion of a re-established muskox population. *Journal of Wildlife Management*. 62: 734-744.

Selvstyret. 2020. Selvstyrets bekendtgørelse nr. 33 af 11. september 2020 om beskyttelse og fangst af ulve. http://lovgivning.gl/lov?rid={30E099A8-76A4-45ED-8602-B7C71975859C}

Tener J.S. 1965. Muskoxen in Canada: A biological and taxonomic review. Canadian Wildlife Service Monograph 2. 166 pp.

Thing H. 1984. Status of the muskox in Greenland. Communication No. 196 from Game Biology Station, Kalø, DK-8410 Ronde, Denmark. *Biol. Pap. Univ. Alaska Spec. Rep. No.* 4: 1-6.

Thomas D.C., Miller F.L., Russel R.H. & Parker G.R. 1981. The Bailey Point region and other muskox refugia in the Canadian Arctic: a short review. *Arctic*. 34(1): 34-36.

Vibe C. 1986. Tilbage til de gamle græsgange. Augut. Pages 6-7. (In Danish)

Appendix 1
Qoororsuaq Valley, south coast Cape Atholl area

Figure 9. Qoororsuaq valley mouth, 16 August 2010: Green vegetated slopes under little auk breeding colonies, view to northeast from mouth of valley. Photo by Peter Lyngs.

Figure 10. Qoororsuaq valley, 03 July 2011: Green vegetated slopes under little auk breeding colonies, taken from inner west slope with view to east. Photo by Peter Lyngs.

Figure 11. Qoororsuaq valley mouth, 02 July 2011: Green vegetated slopes under little auk breeding colonies, view northeast into mouth of valley. Photo by Peter Lyngs.

Figure 12. Qoororsuaq valley mouth, 24 July 2017: Area of green vegetated slopes under little auk breeding colonies appears relatively unchanged since July 2011 (see Fig. 11). Photo by C. Cuyler.

Figure 13. Aerial view of Qoororsuaq valley, 14 September 2017: Vegetated slopes under little auk breeding colonies, view to northeast. Photo by Kasim S. Virk.

Figure 14. Aerial view of Qoororsuaq valley, 14 September 2017, inner valley view to NNE. Photo by Kasim S. Virk.

Figure 15. Aerial view of inner west side of the Qororsuaq valley, 14 September 2017, view NNE. Photo by Kasim S. Virk.

Figure 16. Satellite image of Qororsuaq valley system, May 2010: Downloaded 2021 Google Earth Pro Maxar Technologies. Vegetated areas are of limited extent, see also figures 9-15, 17 and 18.

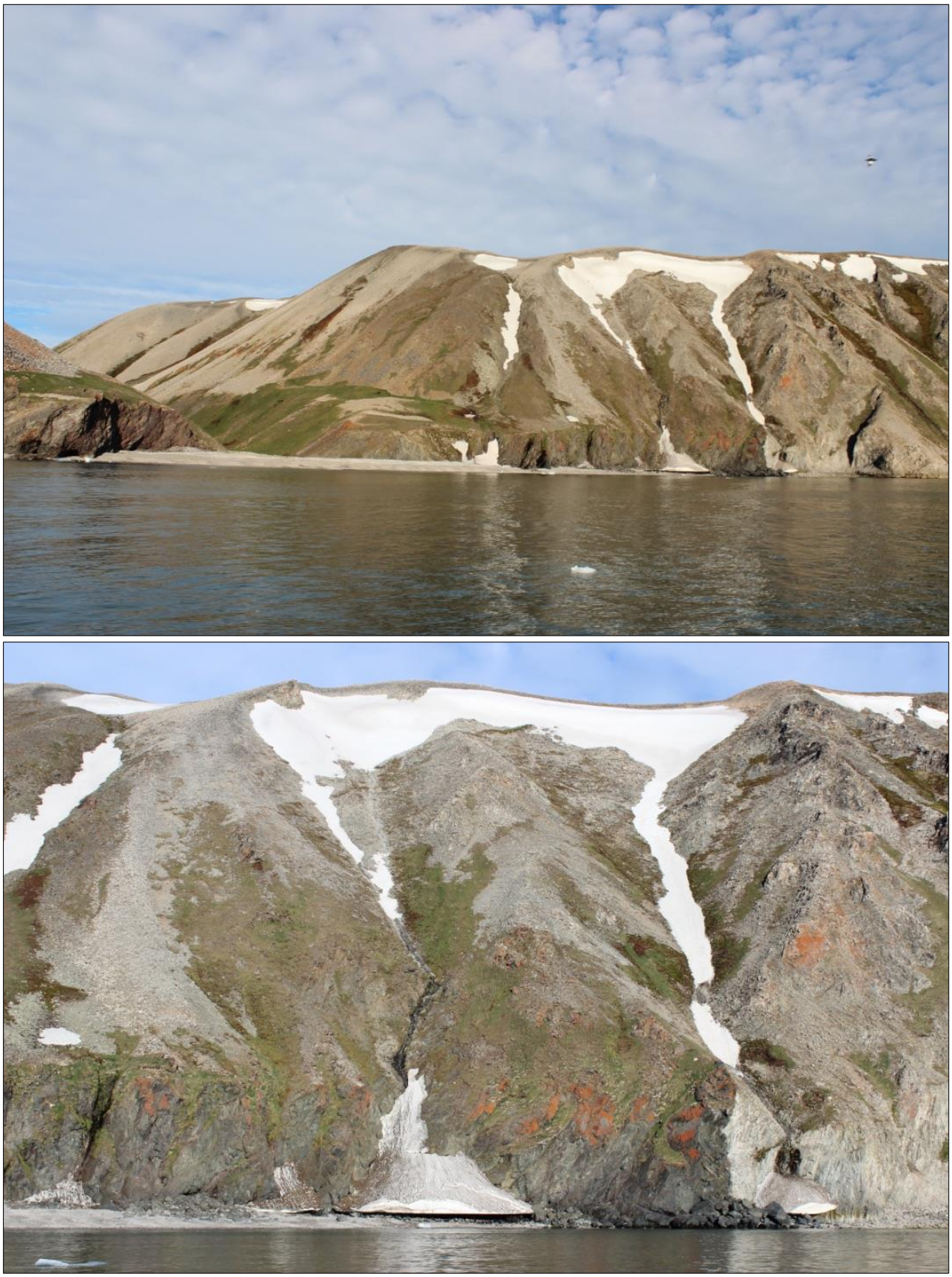

Figure 17. Outer Qoororsuaq valley (above) and closeup of Qoororsuaq shore cliff (below), 24 July 2017. Photos by C. Cuyler.

Figure 18. Further photos of Qoororsuaq valley mouth with closeup, taken 24 July 2017. Photos by C. Cuyler.

Appendix 2

Brief description methods: 2013 polar bear survey

In the period, 7-17 September 2013, seven days could be used for flying searching for polar bears in the area between 74° 34′ N (Kullorsuaq) and 76° 46′ N (Moriussaq; i.e. an abandoned settlement NW of Pituffik – Thule Air Base), and between 57° 14′ W (Kullorsuaq) and 70° 03′ W (western point of Appat/Saunders Island) out to a maximum distance of ca. 40 km from the coast to include offshore islands. An Air Greenland AS350 Ecureuil B3 helicopter was used for searching the coastlines, mountains, glacier fronts, glacial ice, and offshore islands for land-locked polar bears. Surveys were usually flown at 300-600 feet altitude above ground (ca. 100-200 m) depending on topography and landscape and at 100-110 knots (185-200 km/h). All observations of wildlife were systematically noted, including muskoxen. A total of 26 hours and 15 minutes "airtime" were used in active searching for bears and other wildlife (Born et al. 2013). Similar methods were used for the 2012 polar bear survey.

Appendix 3

Field work photos *(taken 24-31 July, unless otherwise indicated)*

Figure 19. Christine Cuyler and Kasim S. Virk, background shows interior of region. Photo by Inge Gottfredsen.

Figure 20. Kasim S. Virk beside the Cessna 172 ready for aerial count 14 September 2017. Hangar and airstrip are located at Dundas, just northwest of the Thule Air Base. Photo by Inge Gottfredsen.

Figure 21. Christine Cuyler steadying telescope while viewing muskoxen. Photo by Inge Gottfredsen.

Figure 22. Low elevation terrain (< 100 m) near the Thule Air Base was typically rocky but occasionally sustained green vegetation of low height, e.g., this valley NE of North Mountain. Photo by C. Cuyler.

Figure 23. Thule Air Base, illustrating minimal vegetation and red brown mud/clay soil. Photo by C. Cuyler.

Figure 24. The iconic flat -topped Dundas Mountain, just NW of the Thule Air Base. Note vegetation is sparce even on the sea level spit of land to the right of the mountain. Photo by C. Cuyler.

Figure 25. Terrain and vegetation typical for around the Thule Air Base. Photos by C. Cuyler.

Figure 26. Terrain and vegetation typical for just east of the Thule Air Base. Photos by C. Cuyler.

Figure 27. A bull muskox grazing among boulders near Thule Air Base. Photo by C. Cuyler.

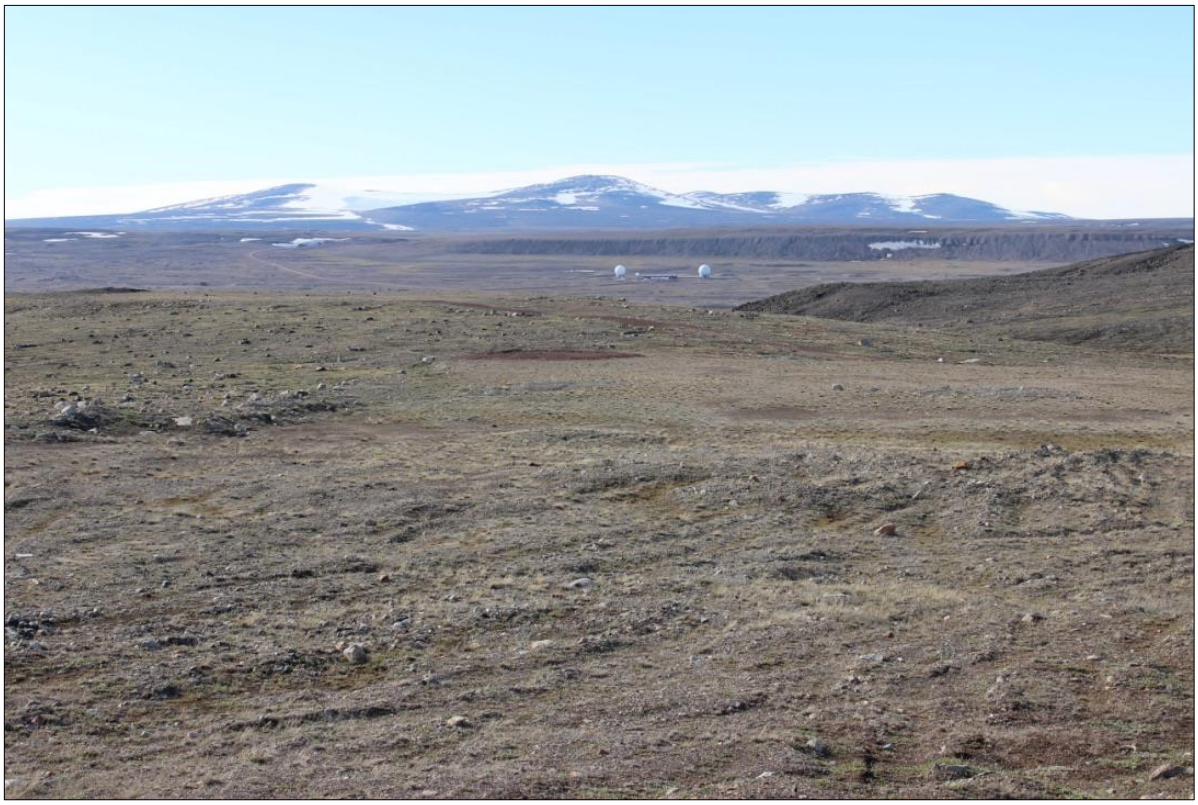

Figure 28. Terrain and sparce vegetation typical to around the Thule Air Base. View looking South across the valley containing the Thule Air Base's radar 'balls' and towards Pingorsuit (P-mountain) massive in background. Photo was taken from eastern end of North Mountain. Photo by C. Cuyler.

Figure 29. Landscapes and sparse vegetation typical of interior and river valleys. Photo by C. Cuyler.

Figure 30. Terrain and sparse vegetation typical at the edge of the Greenland Ice Cap near Camp Tutu. Photo by C. Cuyler.

Figure 31. Typical open vista (view to NE on road east from Thule Air Base) with Greenland Ice Cap in background right of centre: light brown colours dominate the landscape, snow patches (centre) from previous winter are common and green vegetation is sparce and low in height. Photo by C. Cuyler.

Figure 32. Group of four muskoxen grazing on sparse vegetation typical of the interior. Photo by C. Cuyler.

Figure 33. Rocky shore at Amitsuarsuk, Uummannap Kangerlua (Wolstenholme Fjord) with view to NE showing the numerous small and some large icebergs. Photo by C. Cuyler.

*Figure 34. Contrast between the green vegetation on the rocky scree slopes immediately below little auk (*Alle alle*) seabird colonies (above: at Qoororsuaq) and typically brownish vegetation elsewhere on the coast where seabird colonies are absent (below: at Narsaarsuk). Photos by C. Cuyler.*

Figure 35. Contrast between the slim horns and slight boss of cows (above) and the robust thick horns and imposing boss of bulls (below). See also figures 38 and 39 for vertical view of a massive boss typical of adult bull muskoxen. Photos by C. Cuyler.

Appendix 4

Raw Data: Ground (road and sea) minimum count, 24 July – 06 August 2017.

Table 5. Raw data from ground (road and sea) minimum count of muskoxen in Cape Atholl, in the period 24 July – 06 August 2017.

Date	Grid Cell	Total Group Size	Unknown			Calf	COW				BULL					Method	Comments	Other observations
			Age (years)															
			1	2	Adult	< 1	1	2	3	4	1	2	3	4	≥ 5			
24 July	E5	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		
24 July	E5	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		
24 July	C7	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		1 hare
24 July	C8	1	0	0	0	0	0	0	0	0	0	0	1	0	0	sailing coast		
24 July	C8	1	0	0	0	0	0	0	0	0	0	1	0	0	0	sailing coast		
24 July	C8	3	0	0	0	0	0	0	0	2	0	1	0	0	0	sailing coast		
24 July	C8	2	0	0	0	0	0	0	0	0	0	0	0	0	2	sailing coast		
24 July	C8	2	0	0	0	0	0	0	0	0	0	0	1	0	1	sailing coast		
24 July	C9	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		
24 July	C9	3	0	0	0	0	0	0	0	1	0	0	0	1	1	sailing coast	At Cape Atholl	
24 July	C9	3	1	1	0	0			0	1			0	0	0	sailing coast	At Cape Atholl	
24 July	C9	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		
24 July	C9	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		
24 July	C10	7	0	0	0	0	0	1	0	1	0	1	0	1	3	sailing coast	Steep, 2-yr male broken R rear leg	
24 July	D10	1	0	0	0	0	0	0	0	0	0	0	0	1	0	sailing coast		
24 July	D10	1	0	0	0	0	0	0	0	0	0	1	0	0	0	sailing coast		
24 July	D10	8	1	2	4	0				1						sailing coast		
24 July	D11	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		
24 July	D11	3	0	0	0	0	0	0	0	0	0	0	1	0	2	sailing coast		
24 July	E11	1	0	0	0	0	0	0	0	0	0	0	0	1	0	sailing coast		1 hare
24 July	E11	4	0	0	0	0	0	1	0	1	0	0	0	1	1	sailing coast		
24 July	E12	8	0	0	1	1	0	1	2	3	0	0	0	0	0	sailing coast	Grey strips under little auk colony	
24 July	E12	1	0	0	0	0	0	0	0	0	0	0	0	0	1	sailing coast		
24 July	E13	4	0	0	0	0	0	1	0	2	0	1	0	0	0	sailing coast		
24 July	E13	2	0	0	2											sailing coast		1 hare, 2 seals
24 July	E5	6	1	0	3	1				1						sailing coast		
26 July	M8	4	0	0	0	0	0	0	0	2	0	1	1	0	0	driving roads		
26 July	M8	2	0	0	0	0	0	0	0	0	0	0	0	0	2	driving roads	wind ca. 15 m/sec gusts more	
26 July	M6	1	0	0	0	0	0	0	0	0	0	0	0	0	1	driving roads		10 hares
26 July	O5	18	0	0	0	4	2	1	1	4	2	2	1	0	1	driving roads		
27 July	L5	1	0	0	0	0	0	0	0	0	0	0	0	0	1	driving roads	near white fuel tanks	
29 July	L8	1	0	0	0	0	0	0	0	0	0	0	0	0	1	driving roads	near bridge crossing	1 hare
29 July	G7	1	0	0	0	0	0	0	0	0	0	0	0	0	1	driving roads	river bottom, road washed out	
29 July	M8	1	0	0	0	0	0	0	0	0	0	0	0	0	1	driving roads		13 hares
06 Aug	Q6	12	2	2	5	3										driving ATV	In terrain far east of SWS12	
TOTAL		**109**	**5**	**5**	**15**	**9**	**2**	**5**	**3**	**19**	**2**	**8**	**5**	**5**	**26**			**27 hares, 2 seals**

Appendix 5
Raw Data Aerial minimum count, 14 Sept 2017

Table 6. Raw data from aerial minimum count of muskoxen in Cape Atholl, flown by fixed-wing Cessna 172 on 14 September 2017. Observed calf number is included in the number given for total group size.

Grid cell	Total group size	Observed calves	Comments
M-4	2		Likely 0 calves, likely 2 lone bulls
L-4	1		Likely 0 calves, likely a lone bull
N-4	18	4	
O-5	12	2	
O-7	6		Unable to see if any calves present
N-8	3		Unable to see if any calves present
N-9	1		Likely 0 calves, likely a lone bull
K-11	11	2	
J-10	4		Unable to see if any calves present
I-6	4		Unable to see if any calves present
H-7	1		Likely 0 calves, likely a lone bull
G-7	1		Likely 0 calves, likely a lone bull
H-9	8		Unable to see if any calves present
G-9	5		Unable to see if any calves present
G-8	5		Unable to see if any calves present
F-8	1		Likely 0 calves, likely a lone bull
F-6	14	3	
E-5	1		Likely 0 calves, likely a lone bull
D-5	1		Likely 0 calves, likely a lone bull
C-5	1		Likely 0 calves, likely a lone bull
C-6	6	1	
D-6	1		Likely 0 calves, likely a lone bull
E-7	3		Unable to see if any calves present
D-8	1		Likely 0 calves, likely a lone bull
C-9	9	2	
C-8	5	1	
C-7	2		Likely 0 calves, likely 2 lone bulls
D-10	7		Unable to see if any calves present
D-9	4		Unable to see if any calves present
E-10	1		Likely 0 calves, likely a lone bull
D-11	22	3	
E-12	2		Likely 0 calves, likely 2 lone bulls
F-12	6		Unable to see if any calves present
F-11	16	1	
H-11	2		Likely 0 calves, likely 2 lone bulls
I-11	1		Likely 0 calves, likely a lone bull
I-12	10	1	
H-12	1		Likely 0 calves, likely a lone bull
G-12	3		Unable to see if any calves present
G-13	1		Likely 0 calves, likely a lone bull
F-13	9	1	
	212	**21**	**TOTAL**

Appendix 6
Natural mortality, mature bull muskoxen

On the 26 August 2017, near the Pituffik – Thule Air Base, a muskox was found dead of natural causes (Fig. 36). Flemming Hvidberg Jensen photographed the dead bull muskox, which was located near a road east of North Mountain, Pituffik – Thule Air Base. Given the lack of black horn tips, which were worn blunt, i.e., rounded down to below eye level into the white portion of the horn, this was a mature bull well past his prime. By 18 September, this bull muskox carcass was being scavenged by a polar bear (Fig. 37).

Figure 36. Natural mortality of an old bull muskox. Thule Air Base pipeline in upper background of photo on right. Photo F. H. Jensen.

Figure 37. Polar bear scavenging the ca. three-week old carcass of adult bull muskox. Photo K. S. Virk.

Appendix 7
One observation of hoof hyperplasia in 2017

Figure 38. Young mature bull aged 5-6 years shot by Lemme Svensson, August 2017. In this photo, the white fuzz hair behind the horn boss is hidden under the shedding neck hair. The horn tips although long and black, lack the expected sharp tips. Photo by F. H. Jensen.

On 30 August 2017, Lemme Svensson shot a bull muskox during the hunting season. Given the shape, size, and length of horns (tips curl past the eyeball) and horn boss (Fig. 38) combined with extensive white fuzz hair behind and between the horn boss often typical of juveniles (Fig. 39), the age of this bull is estimated to be 5-6 years. Although the horns are long and possess black tips, these are not as sharply pointed as expected for a 5-year-old, and the horn boss looks much worn and chipped for a relatively young mature bull. Already in the late 1990s abnormal horn chipping was documented for muskoxen in Cape Atholl area(Cuyler et al. 2002). Although August, this bull had not yet completely shed last winter's coat, which might indicate suboptimal body condition. A diet involving poor browse was evidenced by extensive tooth wear on the front incisors (not photographed). The right front hoof of

this mature bull muskox was hyperplastic, i.e., somewhat overgrown (Fig. 40) however, the other three hooves were normal. This suggests that hyperplasia of the one hoof resulted from a pathogen, i.e., was not the result of genetics or diet.

Figure 39. White fuzz hair, typical of young bulls, behind (and between) horn boss, which is prematurely old looking being worn and chipped. Photo by F. H. Jensen.

Figure 40. Hyperplasia of the right front hoof from mature bull muskox, age 5-6 years, shot 30 August 2017. Photo by F. H. Jensen.

Appendix 8: Data sheet for ground (road and sea) minimum count (Danish / English)

MUSKOX / MOSKUS, Kap Atholl, THULE, 76.5°N_NW Greenland – JULY/JULI 2017 Minimum Count + Demographics / Minimumstælling + Eloksstruktur 1

Dato	Kort nr.	Total Antal I gruppen	Ukendt ? Unknown ?		Kalv Født 2017	KO ♀♀ COW ♀♀			TYR ♂♂ BULL ♂♂					
Date	Grid Cell	Total Group size	år / year 1-2	år / year ≥ 3	Born 2017 CALF	år / year 1	år / year 2	år / year ≥ 3	år / year 1	år / year 2	år / year 3	år / year 4	år / year ≥ 5	år / year ≥ 10

Appendix 9: Data sheet aerial minimum count (Danish / English)

Date	*Grid Cell*	Total Group Size	Calves 2017	Miscellaneous
Dato	**Kort Felt**	**Total Antal i gruppen**	**KALVE 2017**	**Andet**

[Empty page]